JUN 5 1933

# Heating · Piping and Air Conditioning

*Engineering "High-lights" of*
**The Century of Progress Exposition**

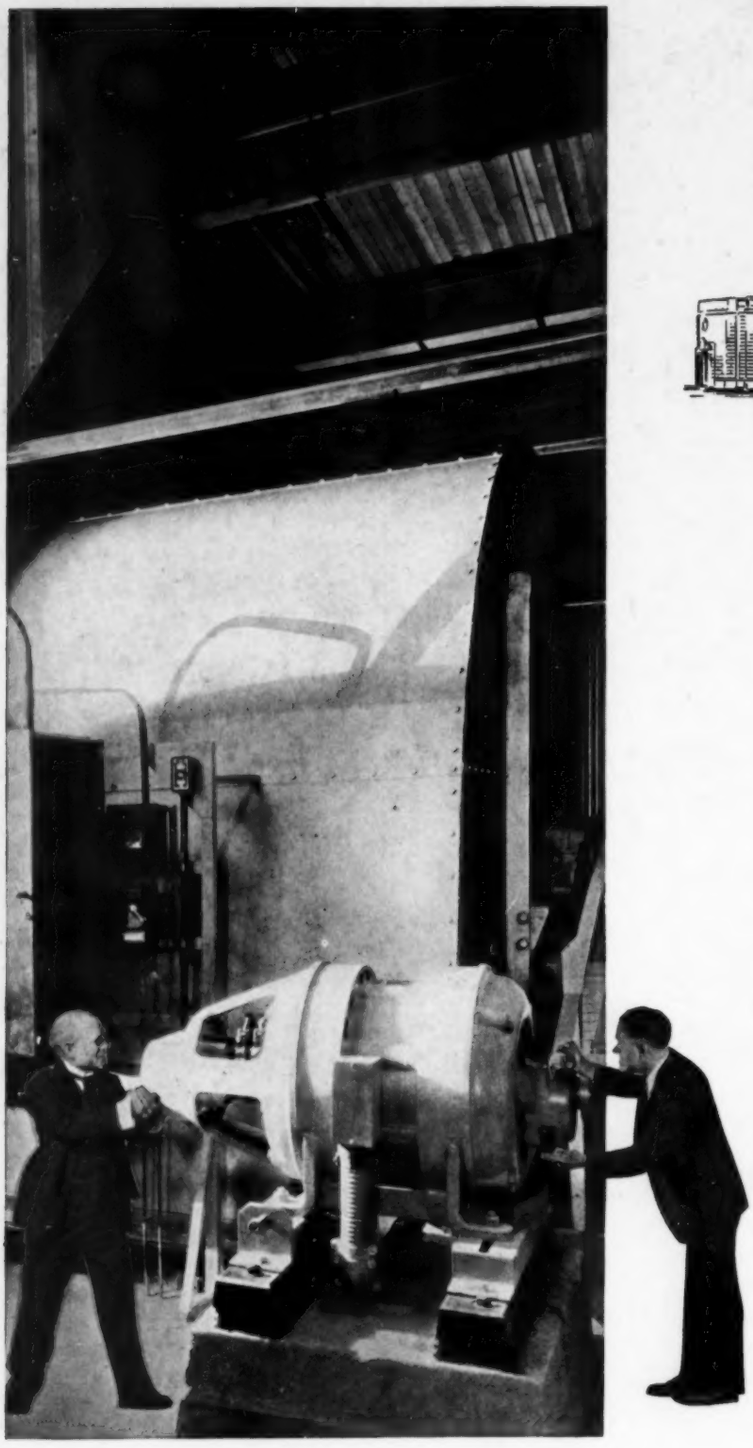
**Product Improvement by Air Conditioning**

**Modernizing Refrigeration Piping**

**Servicing Air Filters**

**Journal Section of the A. S. H. V. E.**

***June, 1933***



"Here's one of the Long Beach Municipal Auditorium's seventeen ventilating fans; all of them are driven by *'Linc-Weld'* motors.

"They tell me that at times some of these Lincoln motors are required to operate under ambient temperatures of 115° F.

"That's what I call making it hot for the motors . . . maybe too hot?"

"Not for 'Linc-Welds'—due to their larger air passages and rapid, complete circulation of air throughout all parts.

"Being cooler in operation is what helps 'Linc-Welds' to deliver that extra horsepower whenever needed.

"If you want more horsepower per dollar, higher efficiency and quiet operation, without sacrifice of power factor, get those 'Linc-Weld' motors . . . made by

# LINCOLN

## THE LINCOLN ELECTRIC COMPANY, CLEVELAND, OHIO

**Manufacturers of *"Linc-Weld"* Motors and *"Stable-Arc"* Welders**

M 8

# Heating · Piping and Air Conditioning

## THE EDITOR'S PAGE

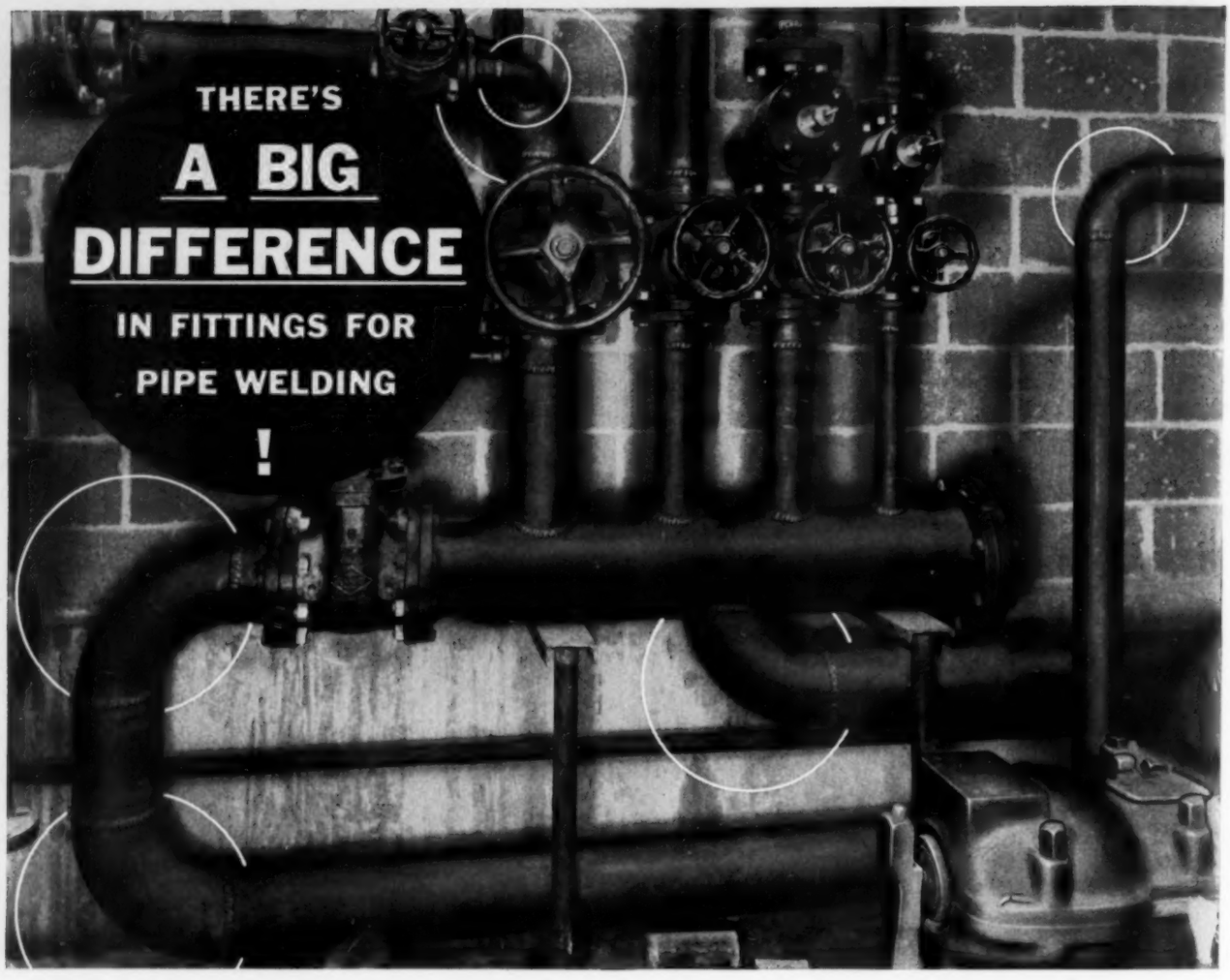
AS this is written, aerial bombs are announcing the opening of the Chicago World's Fair, the building of which we have watched from our office windows. Many readers will visit it during coming months, particularly in June. During "Engineering Week," many of the national societies and associations will meet here and others are scheduled for following months. The Chicago power show (where we will have a booth) at the Stevens hotel will also be a major attraction. Features of the Fair in which you will be particularly interested are "high-lighted" in the lead-off article this month.

MENTIONED in the introduction to Emory Kemler's article this month is the fact that it has been only in comparatively recent years that many process liquids have been piped. Piping plays a part of increasing importance in industrial processes.

Data enabling the rational design of process piping for many materials are meager or entirely unavailable. For this reason, many piping systems have been put in by rule-of-thumb methods, which have not always been as satisfactory as might be. Kemler's series of articles —this month's is the second—contains much information of value in the design of a piping system for a process liquid.

CHARLES S. LEOPOLD—consulting engineer and a member of our Board of Consulting and Contributing Editors—has an enviable standing in air-conditioning work. His article in this issue describes the results which have been achieved with a compressor-equipped plant arranged to store refrigerating effect for a conditioning system in an office-building restaurant. In a later issue it is hoped to present an article which will describe the design and operating details of this plant.

IN a field as active as is that of heating and air conditioning, developments—both in technique and in equipment—come fast and furious. There are many changes in the short interval of, say, four years ago, when HEATING, PIPING AND AIR CONDITIONING made its initial bow. To present the latest information on the design, installation, operation, and maintenance of heating, piping, and air conditioning systems in industry and large buildings is our constant aim.




ASIDE from engineering differences such as smooth inner walls, uniformity of wall-thickness, etc., one of the greatest dissimilarities between Tube-Turns and other fittings is *this:*

Tube-Turns are the ONLY stock fittings for pipe welding that have *proven* their ability to stand up under severe conditions over long periods of time.

Hundreds of Tube-Turn installations have now been in all kinds of the most difficult service for six years, and are giving perfect satisfaction.

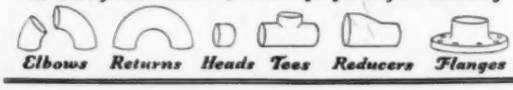
(*Question:* What *other* fittings for pipe-welding had ever been heard of, even *three* years ago?)

Tube-Turns have *proven* their right to your confidence. They are the *only* fittings forged from seamless tubing, without thickening of inside walls, without thinning of outside walls, and without the stresses induced by bending operations.

They have the same radius of curvature throughout the turn—hence greater freedom of flow. *They have uniform wall-thickness at ALL points* . . . . And there are still *other* differences that bring about worth-while differences in both life and performance. *Write* for all the facts. No obligation, of course. *Address:* TUBE-TURNS, *Incorporated*, 1309 South Shelby Street, Louisville, Kentucky.

TUBE-TURNS

*A Complete Line of Fittings for Pipe Welding*



*Elbows Returns Heads Tees Reducers Flanges*

BOARD OF CONSULTING & CONTRIBUTING EDITORS

*Heating*

Samuel R. Lewis
Alfred J. Offner
E. B. Langenberg
James C. Peebles
John D. Small
Homer R. Linn
Lee P. Hynes
Frederick D. Mensing
R. P. Schoenijahn
A. K. Ohmes
J. C. Hornung
A. Beaurrienne
T. S. Tenney

*Piping*

A. W. Moulder
Sabin Crocker
R. C. Doremus
E. O. Eastwood
David J. Jones
George B. Mulloy
J. J. Harman
C. W. Kimball
A. R. Acheson
Percy R. Owens
E. L. Ellingwood
W. H. Wilson

*Air Conditioning*

Dwight D. Kimball
Walter L. Fleisher
John Howatt
Charles S. Leopold
Frank B. Rowley
Alfred Kellogg
John F. Hale
E. P. Heckel
H. C. Murphy
Philip Drinker
R. S. Hawley
William A. Hanley

●

CHAS. E. PRICE
*Editor*

C. M. BURNAM, JR.
*Engineering Editor*

# TABLE OF CONTENTS—JUNE, 1933

Vol. 5 No. 6

A Century of Progress Exposition ..... 289

Movie-Makers Teach a Lesson in Product Improvement by Air Conditioning, by L. H. Polderman ..... 292

Some Practical Pointers on Modernizing Refrigeration Piping, by R. C. Doremus ..... 294

Reduces Air-Conditioning Costs with Compressor-Equipped Plant Storing Refrigerating Effect, by Charles S. Leopold ..... 296

The Flow of Fluids in Pipes, by Emory Kemler ..... 298

Servicing the Air Filters for 140 Unit Ventilators, by W. H. Junker 302

Operation, Maintenance of Cloth-Screen Dust Collectors, by W. F. Terry ..... 304

New National Archives Building Conditioned to Protect Records... 305

Calculating Heating Surface for Buildings, by Price L. Rogers.... 306

Interesting Equipment Developments ..... 307

Recent Trade Literature (Advertising Section) ..... 78

Advertisers' Index (Advertising Section) ..... 80

● ● ● ● ● ●

## Journal Section of the *American Society of Heating and Ventilating Engineers*

The Heat Conductivity of Wood at Climatic Temperature Differences, by F. B. Rowley ..... 313

Indices of Air Change and Air Distribution, by F. C. Houghten and J. L. Blackshaw ..... 324

Bulletin Section ..... 331

Published Monthly by ENGINEERING PUBLICATIONS, INC. 1900 Prairie Avenue, Chicago

TERMS OF SUBSCRIPTION

Anywhere in the world, $2.00 per year.
Current copies, 25c each. Back numbers, 50c each.
Member Audit Bureau of Circulations.
Member The Associated Business Papers, Inc.

F. P. Keeney, *President and Treasurer*
E. DeForest Winslow, *Vice President*
O. T. Carson, *Secretary*

Address all Correspondence to Chicago Office.

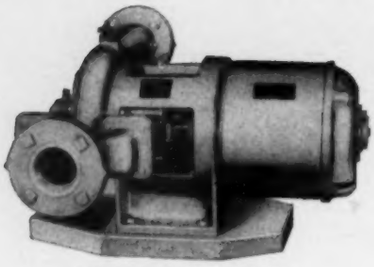
New York Office, Room 1706-1707, 110 East 42nd Street.
Pittsburgh Office, Room 604, Chamber of Commerce Bldg.

Copyright, 1933, by Engineering Publications, Inc.

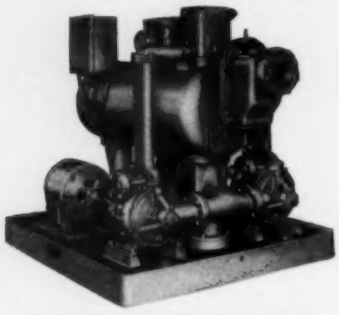
*Advertising Representatives:* E. G. Hutchison, R. Payne Wettstein, W. J. Osborn, H. J. Carr, R. A. Jack, A. T. Papineau, M. P. Driscoll

# NASH

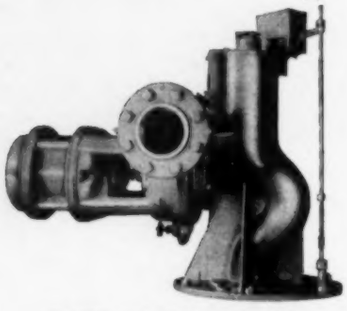
## THE ECONOMICAL ANSWER TO EVERY PUMPING PROBLEM



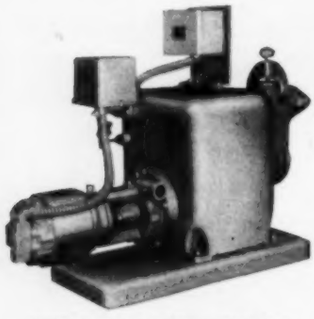
**CENTRIFUGAL PUMPS**
STANDARD AND SELF PRIMING
Motor armature and pump impeller mounted on same shaft. No bearings in pump casing. One stuffing box. Simple, Compact, Reliable.



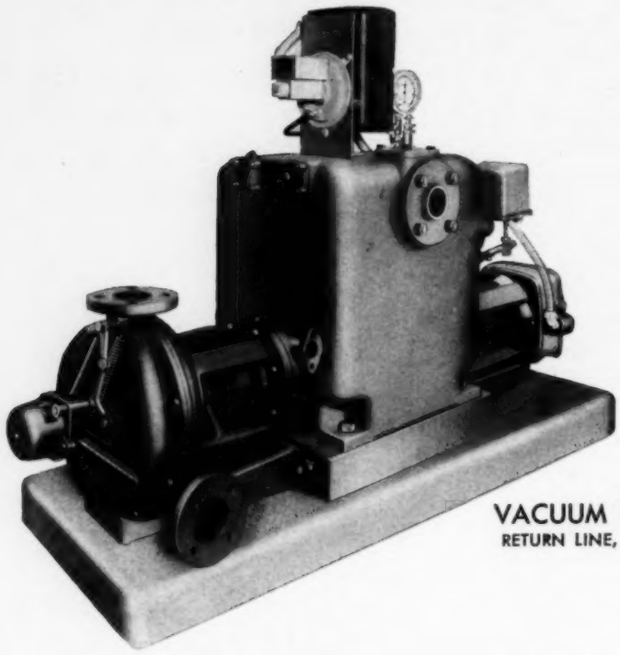
**VACUUM HEATING PUMPS**
STANDARD RETURN LINE
Over 45,000 installations offer testimony to the excellence of these pumps. They furnish greater pumping capacity with less horse power and at lower cost.



**SUCTION SUMP PUMPS**
ENTIRELY SELF PRIMING
In two types for sump and sewage service. Mounted entirely above the pit cover. All working parts high and dry. Only suction pipe submerged. Simple. Economical.



**CONDENSATION PUMPS**
IN UNIT AND STANDARD TYPES
Removes condensation from radiators set below boiler water line level and returns it to boiler. In Unit Type, illustrated, pump casing forms part of return tank. Construction is economical, and saves floor space.



**VACUUM HEATING PUMP**
RETURN LINE, VAPOR TURBINE TYPE

You would find it difficult to pass a single day without coming in contact in some way with Nash Pumping Equipment. For instance, your breakfast coffee probably came to you in a can made with the aid of Nash Pumps. Any large building where you transact business may be serviced by Nash Heating Pumps. Consider paper alone. Eighty-one per cent of all the paper made in the United States and Canada is processed with Nash Pumps at some point in its production. In other fields it is the same. There are over forty-five thousand installations of just one of the types shown on this page.

The Jennings Vapor Turbine Return Line Vacuum Heating Pump shown at the top of this page is a new member of the Nash family. Here is a pump which eliminates electric current, the one largest cost item in the operation of a heating pump.

For this device functions on steam directly from the heating mains, and returns that steam to the heating system. As it operates on a differential of only 5″ of mercury between inlet and exhaust the heat loss is negligible. It works equally well on any steam heating system, high pressure, low pressure or street steam and regardless of type of steam control.

Bulletin 203 gives some interesting details concerning this economical and efficient pumping unit. Why not send for your copy?

## NASH ENGINEERING COMPANY
## SOUTH NORWALK, CONNECTICUT

Heating · Piping
and Air Conditioning
Vol. 5, No. 6 June, 1933

*MANY READERS will visit Chicago this summer to attend the meetings of the various societies and associations and to visit the World's Fair. . . . Much is to be seen of educational importance. . . . We attempt to review in the space here available some of the features of*

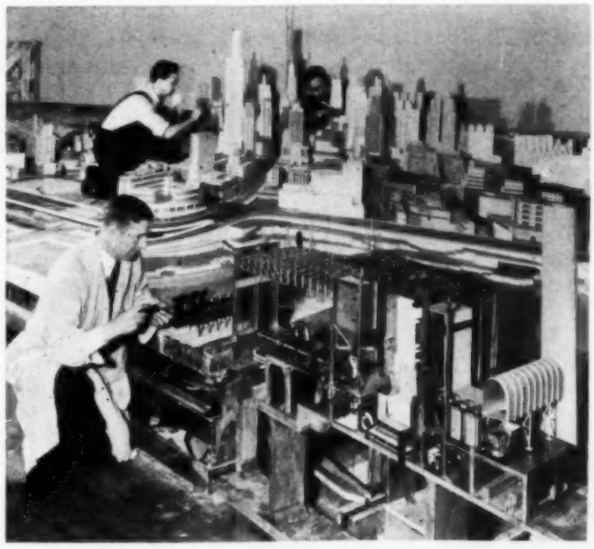
# A Century of Progress Exposition

PROCESSES—not products—is the theme around which the Century of Progress International Exposition, Chicago World's Fair, has been built. Opened Saturday, May 27—and scheduled to remain open through October—the riotously-colored, "modern style" buildings of the exposition probably contain more informative and educational exhibits than have ever before been gathered in one area. The readers of HEATING, PIPING AND AIR CONDITIONING attending the various society and association meetings to be held in Chicago this summer will find much of interest at the Fair, as progress during the past century has been in the main an engineering and technological development. In recognition of this, June 25-30 will be "Engineering Week," with "Engineers' Day" on Wednesday, June 28.

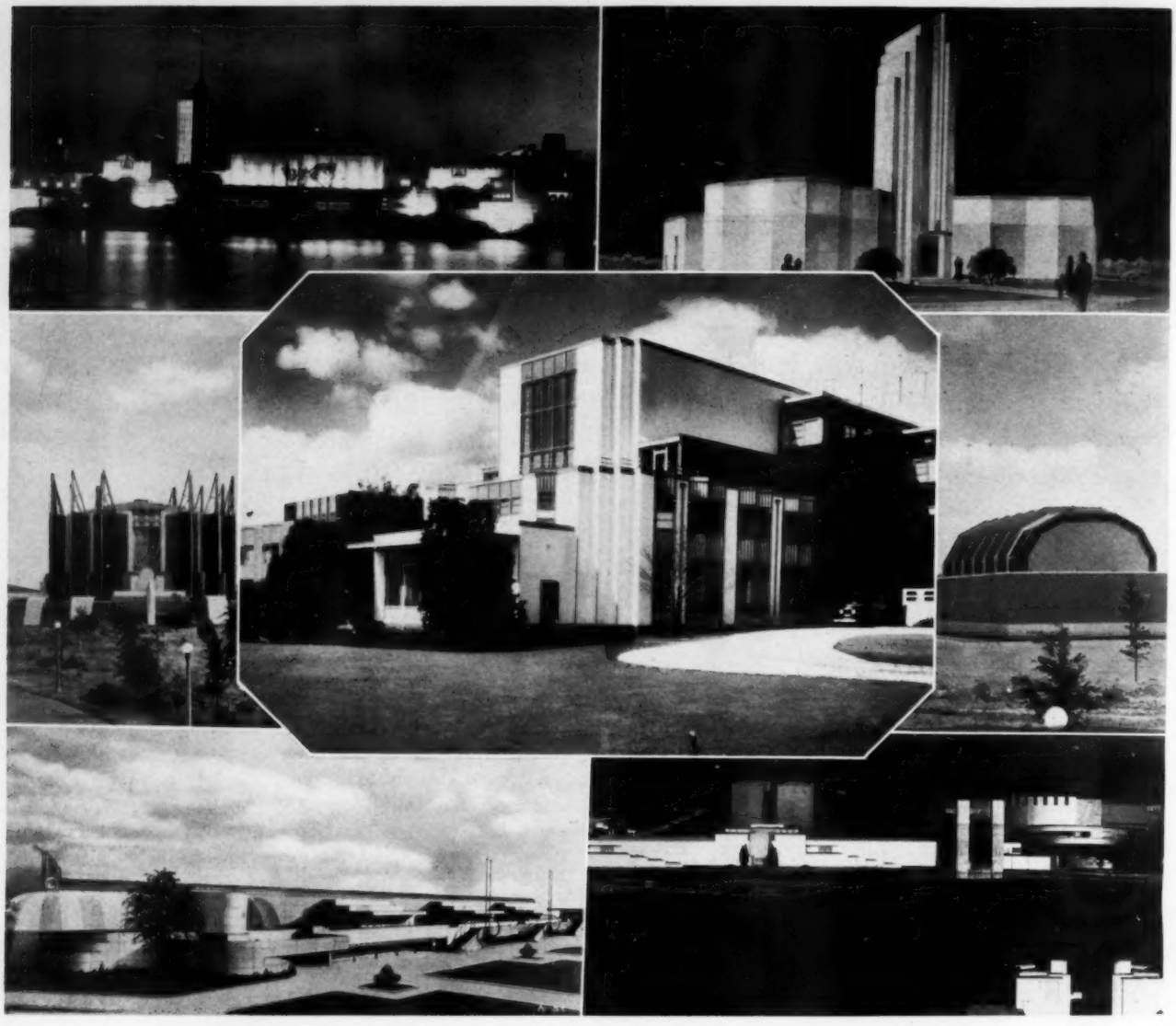
The Fair runs to extremes—more people have paid admissions for previews during construction than ever before—the architecture and coloring of the buildings have probably caused more arguments *pro* and *con* than have any other—the twin towers of the "sky-ride" are the highest points west of New York City—the midget village is called the smallest in the world. The grounds run along the shore of Lake Michigan from 12th St. south to 38th and such problems as transportation to, from and within the Fair grounds have been given careful consideration, as have the other problems of crowd-control. Lighting is to be a particular feature.

As described in a short article last month, the buildings—naturally of temporary construction—will be kept comfortable by exhausting from them a rather large quantity of air. The only one of the Exposition buildings that is heated is the Administration Building, which has already been in use for two winters. The main points of interest to the readers of HEATING, PIPING AND AIR CONDITIONING will be in the exhibits themselves, of which there are a variety. To describe them completely would be impossible. Our purpose is to mention some of the "high-lights."

**Fig. 1—Putting the finishing touches on the largest diorama ever made, part of the exhibit of the electrical industry which shows the production and distribution of electrical power, and its many uses in industry and for other purposes**



One most fascinating exhibit is that of the electrical-central-station industry in the Electrical Building (Fig. 7). It occupies the semi-circular second floor, a space about 550 ft. long. Conspicuous among its features is the 90-ft diorama (Fig. 1) depicting the production and distribution of electricity. This immense plastic picture shows a high-head water power plant at a mountain foot, a low-head hydro plant utilizing the greater volume and lesser fall of water farther down



on the plain and a steam station located in a populous city. Transmission lines and substations link these power producers into an interconnected system from which are fed the businesses and industries, the homes and farms.

The diorama is animated with lights and flowing water, spinning turbines and all the movement of busy life. A recorded voice issuing from a hidden source points out the features of the diorama and traces the flow of electricity from generation to final use. A sequence of light and darkness on the scene simulates day and night so that the observer sees windows begin to glow at dusk and shadowy streets become paths of brightness.

The utilization of electricity, however, is the major burden of the exhibit; there are six main divisions of this display showing the uses of electricity in commercial buildings, in schools and colleges, in hospitals and public health institutions, in various industries, in the home and on the farm. Typical of these is the one-fourth actual size model of a schoolroom, completely air conditioned, and with automatic control of lighting, etc.

**Some of the buildings at "A Century of Progress." Fig. 2 (center)—A view of the Administration Building at the Fair. Fig. 3 (upper left)—Hall of Science, indicating the novel lighting effects. Fig. 4 (upper right)—Exhibit building constructed of glass blocks. Fig. 5 (sides)—Travel and Transport group. Fig. 6 (lower left)—Agricultural Building. Fig. 7 (lower right)—The electrical group**

### Air-Conditioned "House of Magic"

In its exhibit in a great semi-circular space on the first floor of the Electrical Building, General Electric is featuring its "house of magic," an auditorium seating 300 persons and in which the wonders of modern science and engineering will be dramatized. The auditorium itself is built to take advantage of this company's developments, as it is completely air-conditioned and will be warmed by an oil furnace in cool weather.

Outside this auditorium are interesting displays of G. E. products and processes, many of them in operation. Among these is a model of the 20,000-kw mercury-vapor-turbine station at Schenectady of particular interest to piping engineers. For those who want to see what makes the

wheels go round, there is a cut-away turbine which shows what happens from the time steam is introduced into the machine until it is exhausted. To show how a nest of gears will cut down speed from 1800 to as low as 13 rpm without loss of power, there is a gear-motor, a section of the enclosing case cut away.

For use in hospitals, hotels, apartment buildings, and office buildings where mechanical noises are undesirable, there is a new motor designed especially for quiet operation, and there is still another motor being operated in a tank with water splashing over it. An electric welder, electrically-operated valves, pilot devices for magnetic control, and an explosion-proof motor are also among the displays, as are demonstrations of the uses of photo-electric tubes.

### Electricity in Industry

The display of the Westinghouse company in the southern half of the great hall in the Electrical Building shows modern uses of electricity in industry, latest means for generation and distribution of power, advances in transportation, in the home, and portrays research accomplishments. Wherever practical, the displays have been made to work and arranged so the visitor can operate the exhibit. A balcony serves as a canopy for the main display on the ground floor, and contains the research exhibit.

Among the many exhibits on the main floor is the circuit breaker display, which illustrates the new de-ion breakers. By pushing a button the visitor can throw a short circuit of more than 1000 hp on the breaker. To supply this exhibit is a 300-kw motor-generator set which will be short-circuited dozens of times a day.

Hanging in the air 35 feet from the ground and slowly revolving is the spindle of a steam turbine of 100,000-hp, the spindle made of wood but fitted with all the thousands of curiously-shaped blades which drive the original machine. Another display of particular interest is that of the supervisory oil-pipe-line control. A working model of a pumping station is shown with its three electrically-driven pumps and its elaborate control devices; a few feet away is the control station, from which the visitor can control all the performance of the pumping station, starting any one of the three motor pumps or any combination.

At one end of the display on the main floor is a full-scale model of the most powerful transformer ever built, the tank itself as large as many a two-story cottage with a towering column of insulators on top. There is nothing inside the tank except a dark room which is used for the exhibit of the remarkable effects of ultra-violet light. The interior is air-conditioned by two suspended-type units.

Other displays trace the developments and applications of motors and controls, etc.

### Shows How Motor Works

Yet another electrical exhibit of particular interest is the model motor exhibited in Century Electric Company's booth, which is arranged to show the electrical happenings in a three-phase, four-pole squirrel-cage induction motor. The three phases in the stator are illustrated with six colors and with three slots per phase, to indicate the magnitude and time of the current flow in the coils. The change of direction of flow of the current is indicated by a change in color. The change in color is controlled through dimmers which gives the effect of the rotating field. Each phase in turn builds up to a maximum in one direction and back through zero, changing color and building up to maximum to complete the cycle. The resultant magnetic field produced by the three-phase action is illustrated by black dashes on a clear disc, the direction of the flux being indicated by arrows. This magnetic field is rotated at the same speed as the sequence of current happenings in the stator.

In addition to this educational model, this company is displaying its fans and motors.

### Glass-Block Building Houses Air-Filter Exhibit

One of the most interesting examples of building construction which will be seen by the Fair visitor is a tower and building constructed entirely of glass blocks by Owens-Illinois Glass Company (Fig. 4). Among the exhibits of this company's products in this building is the glass-wool air filter, which will be shown in such manner as to give an appreciation of the wide

(*To page 66, back Advertising Section*)

### Conventions and Expositions

*National Warm Air Heating Association:* Mid-year convention, June 6-8, Hotel Stevens, Chicago. Managing director, Allen W. Williams, A. I. U. Building, Columbus, Ohio.

*American Oil Burner Association:* Annual convention and exposition, June 12-16, Hotel Stevens, Chicago, Ill. Secretary, H. F. Tapp, 342 Madison Ave., New York City.

*American Society of Heating and Ventilating Engineers:* Semi-annual meeting, June 22-24, Hotel Statler, Detroit, Mich. Arrangements being made for visiting Chicago World's Fair after meeting. Secretary, A. V. Hutchinson, 51 Madison Ave., New York City.

*Engineering Week, A Century of Progress:* June 25-30, Chicago. (Engineers' Day, June 28.) Engineering Societies Committee, 205 W. Wacker Drive, Chicago.

*American Society of Mechanical Engineers:* Semi-annual meeting, June 25 30, Palmer House, Chicago. Midwest Office, 205 W. Wacker Drive, Chicago.

*American Society for Testing Materials:* Annual meeting June 26-30, Hotel Stevens, Chicago. Secretary, C. L. Warwick, 1315 Spruce St., Philadelphia, Pa.

*Midwest Engineering and Power Exposition:* June 25-30, Hotel Stevens, Chicago. Headquarters, 308 W. Washington St., Chicago.

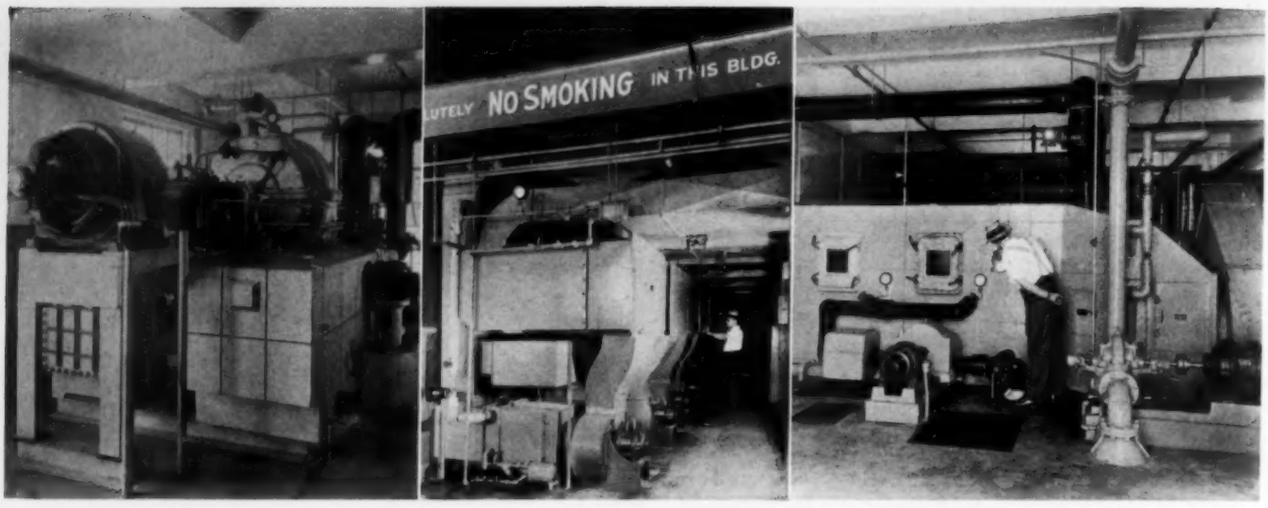
*National District Heating Association:* Annual convention, June 26-28, Hotel Sherman, Chicago. Secretary, D. L. Gaskill, 603 Broadway, Greenville, Ohio.

*American Society of Refrigerating Engineers:* Summer meeting, June 26-28, Hotel Sherman, Chicago. Secretary, David L. Fiske, 37 W. 39th St., New York.

*American Welding Society:* Worlds Fair meeting, June 29, Congress Hotel, Chicago. Secretary, M. M. Kelly, 33 W. 39th St., New York.

*Heating and Piping Contractors National Association:* Annual convention, July 25-28, Chicago. Secretary, J. C. Fitts, 50 Union Square, New York City.

*American Gas Association:* Annual convention, September 25-29, Chicago. Headquarters Office, 420 Lexington Ave., New York City.




**Left—Refrigerating unit which supplies cold water to the air- and solution-control systems in the M-G-M film-developing laboratory. Center—Battery of individual air-circulating units serving developing machines and drying cabinets on the floor above. Right—One of the two central-station dehumidifying and air conditioning units which serve the film-developing laboratory**

# *Movie-Makers Teach a Lesson in*
# Product Improvement by Air Conditioning

*By* **L. H. Polderman***

CONTRAST the pleasure in viewing motion pictures today with the eye-straining "flickers" of yesteryear.

Remarkable improvement has been accomplished in bringing almost true images to the screen. While traceable to perfections in many phases of production and presentation, this progress is due in great measure to the application of air conditioning to the developing processes.

In the early days of the motion-picture industry crude methods of developing were employed, with even cruder methods of heating and cooling of air and solutions in the laboratories. Since then, the air-conditioning engineer has cooperated with the developing engineer to increase the quality and speed of output and reduce the cost of film treatment. As a result, air conditioning has become indispensable to all of the film-developing processes—as it has in every industry processing hygroscopic materials.

### Developing Film at the M-G-M Plant

The newest and one of the largest U. S. film laboratories is the Metro-Goldwyn-Mayer developing plant on the M-G-M lot at Culver City, Calif. The building is two-story, of fireproof brick, steel and concrete construction. The plant has a capacity of approximately 6,000,000 feet of film a week, 312,000,000 feet a year.

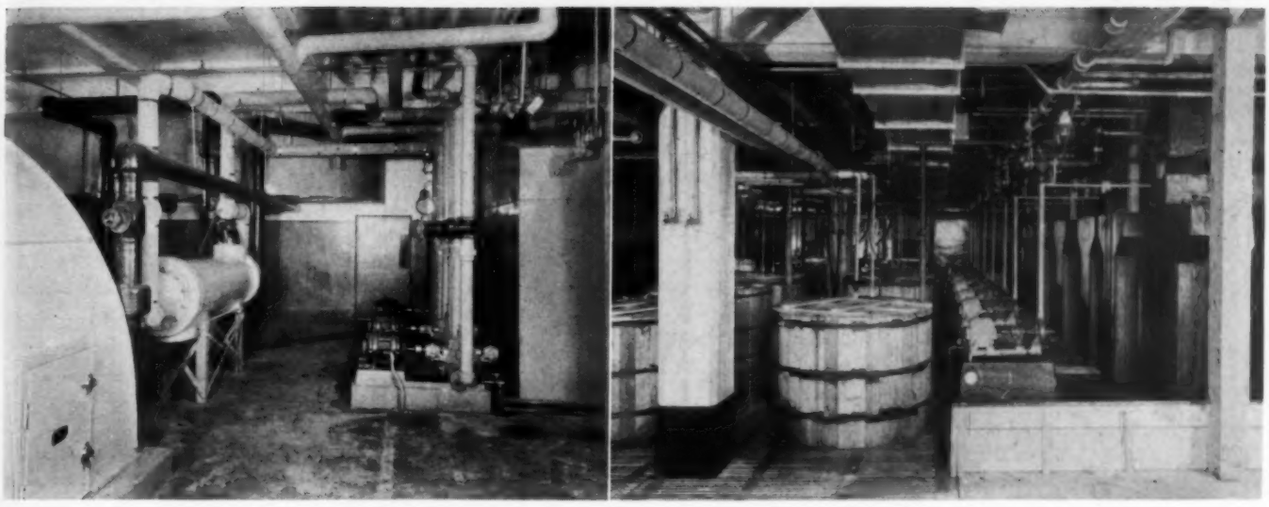
Briefly, the production procedure is this: Film is taken from camera cases after exposure and is run through developing solutions; solutions are washed off and then film is sent through drying cabinets. It is then cut and assembled into reel and picture lengths to form the master negatives. The negatives are used to print positives on raw film. The positives are then developed, washed, and dried in the same manner as the negatives, except that they require less time. Developed prints are then projected for quality inspection, after which they are packed for shipment.

### Air Conditioning Maintains Production Schedule

Strict maintenance of the plant's production schedule and rigid quality requirements is accomplished throughout the year only with the aid of air conditioning. Every portion of the laboratory in which film is handled—excepting the storage and shipping room—enjoys the benefits of ideal and uniform conditions of temperature and humidity. The equipment was designed especially for the M-G-M laboratory and was installed at the time the building was erected, little more than a year ago.

First and most important of the problems air conditioning solves is elimination of dust. The film, when presented, is magnified several hundred times from the projector to the screen and should a tiny speck of dust be allowed to lodge on its delicate surface in the course of development it would adhere and become a part of the film, to assume huge proportions upon projection. Then, too, dust particles in the laboratory might scratch the film and cause many another annoyance and damage.

* Vice-president, Carrier Engineering Corporation of California, Los Angeles.



**Left—Apparatus room in the developing laboratory, showing interchanger and cold-water circulating system for developing-solution control. Right—Developer collecting and holding tanks are at the left of this view and the solution circulating and temperature-control systems serving the positive film-developing machines are on the right. Developing machines on floor above**

Second is the maintenance of constant temperature and humidity in the various dry rooms and cabinets. The use of individual automatic temperature and humidity controls in drying rooms or cabinets permits positive drying schedules to be maintained regardless of outside atmospheric conditions. This eliminates possibility of curling and distortion of the gelatin surface, and contributes to the production of a soft, pliable, flat film.

Third is the control of temperature and humidity in the various work rooms. The atmosphere in these rooms should be sufficiently humid to prevent the film from becoming too dry and brittle. A brittle film is very difficult for the printing machines to handle, and is likely to break. A high humidity in the printing rooms reduces static electricity and avoids a tendency to fog the film.

Control of the temperature of the solutions used in developing is another factor. Usual practice is to hold the temperature of these solutions within ± 0.5 F. The reason for such accuracy is that the relationship between the time of development and the temperature of the solution is fixed. Then, any variation of temperature in the solution means a variation of tone values in the finished film. Modern laboratory air-conditioning equipment must, therefore, include a refrigeration system which, by means of its automatic features, maintains the temperatures of the developing and fixing solutions at constant and desired values.

Since pictures have learned to talk the developing process has been further complicated. Sound-track negatives, after being developed, must be synchronized perfectly with the positive film, and the close control of the humidity and temperature of the various work rooms has helped to simplify this problem. Without control, variations of relative humidity produce corresponding variations of the moisture content of the films, resulting in changes of size and length and making synchronization exceedingly difficult, if not impossible.

### The Air- and Solution-Control Systems

The air- and solution-conditioning and handling system includes two central-station air-conditioning units and a centrifugal refrigeration unit. Inter-connected with the refrigeration machine exclusively serving the laboratory's needs is a second unit located in another building so the laboratory processes may be uninterrupted in any emergency. The laboratory system differs from the ordinary for, in addition to the usual ducts from the central-station air-conditioning units to the various work rooms in the building served, there are individual air-circulating units for the twelve positive-and-negative film-drying cabinets. Then there is a solution-control system which sets and maintains the temperature of the developer and a circulating system to handle the solutions from the mixing tanks or storage tanks to the developing machines and return.

The solution-control and circulating system is, of course, not air, but liquid, conditioning, yet as an aid in

(*To page 74, back Advertising Section*)

*Those who process hygroscopic materials —from matches to medicines, textiles to tissue paper—have one problem in common. The control of temperature and humidity is essential to the manufacture of products from hygroscopic materials, if such processing is to be efficient, economic. . . . Air conditioning has been applied to over two hundred industries; others are constantly learning that proper temperature and humidity control can offer worthwhile freedom from uncontrolled climatic conditions.*

*By* **R. C. Doremus***

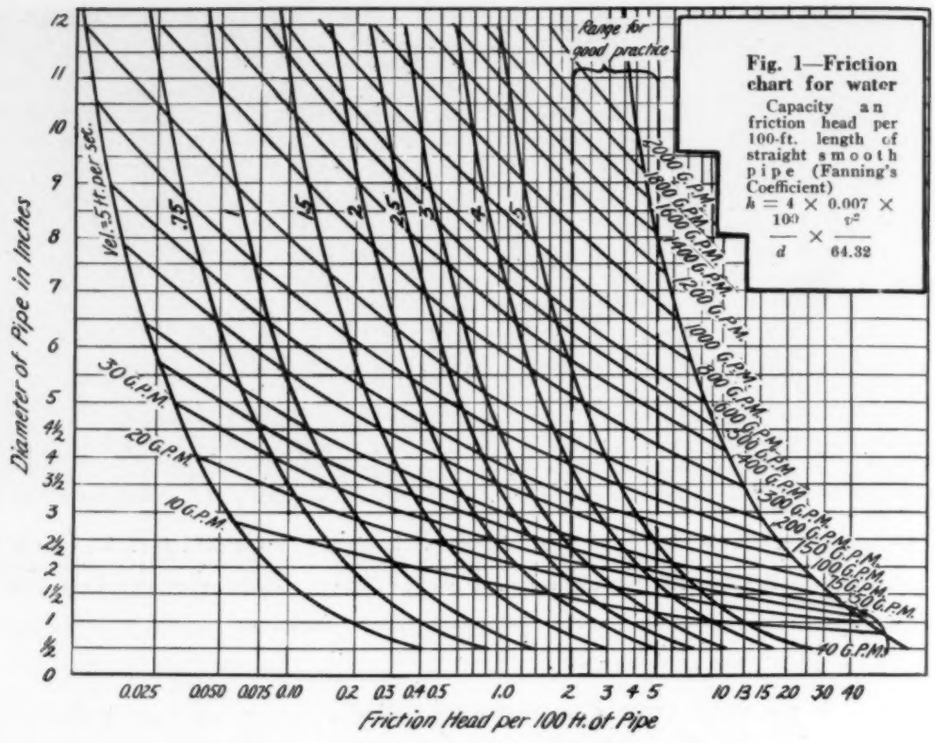



**Fig. 1—Friction chart for water**

Capacity and friction head per 100-ft. length of straight smooth pipe (Fanning's Coefficient)

$$h = 4 \times 0.007 \times \frac{100}{d} \times \frac{v^2}{64.32}$$

# *Some Practical Pointers on*

# MODERNIZING

# Refrigeration Piping

PIPING in the industrial refrigeration plant represents a large capital investment that must be carefully weighed in any design. The ordinary cold-storage plant, for example, is equipped with pipe which if placed in one continuous length would reach from 20 to 100 miles. The refrigerating engineer and the industrial engineer concerned with the operation of a refrigeration plant must be thoroughly familiar with the piping in order to use it to the best advantage. The pipe used in any industrial refrigerating plant may be classified in two groups:

1. Piping used as heat-transfer surface.
2. Piping used as conduit for refrigerating fluids.

The modernization of piping used as heat-transfer surface was considered in the April issue. The present article is devoted to the modernization of piping conduit or mains for handling refrigerating water and brine; in a later issue, the piping of ammonia will be the subject and, following that, information helpful in modernizing piping for other refrigerants will be given.

*George B. Bright Co., Refrigerating Engineers and Architects, Detroit, Mich. Member of Board of Consulting and Contributing Editors.

### The Need for Piping Modernization

Plant piping is sometimes quite roughly estimated and sometimes shows up characteristic faults; a piping check-up of existing jobs is distinctly a paying proposition. For example, one ice-manufacturing plant in Illinois was originally built as a 60-ton plant with provisions in the piping for doubling to 120-ton capacity. It was doubled and still later a third tank, which was not contemplated, was added. Proper machine capacity was installed, but rated production fell short of the anticipated amount.

The mechanical equipment was examined, speeds and temperatures checked, but nothing could be done to improve the situation, inasmuch as the extremely high vapor velocities in the piping mains formed a bottleneck. This was corrected and the trouble eliminated. Not only was rated production obtained, but the total machine capacity was used only in the hottest summer weather, and manufacturing cost per ton was considerably decreased, due to increased production.

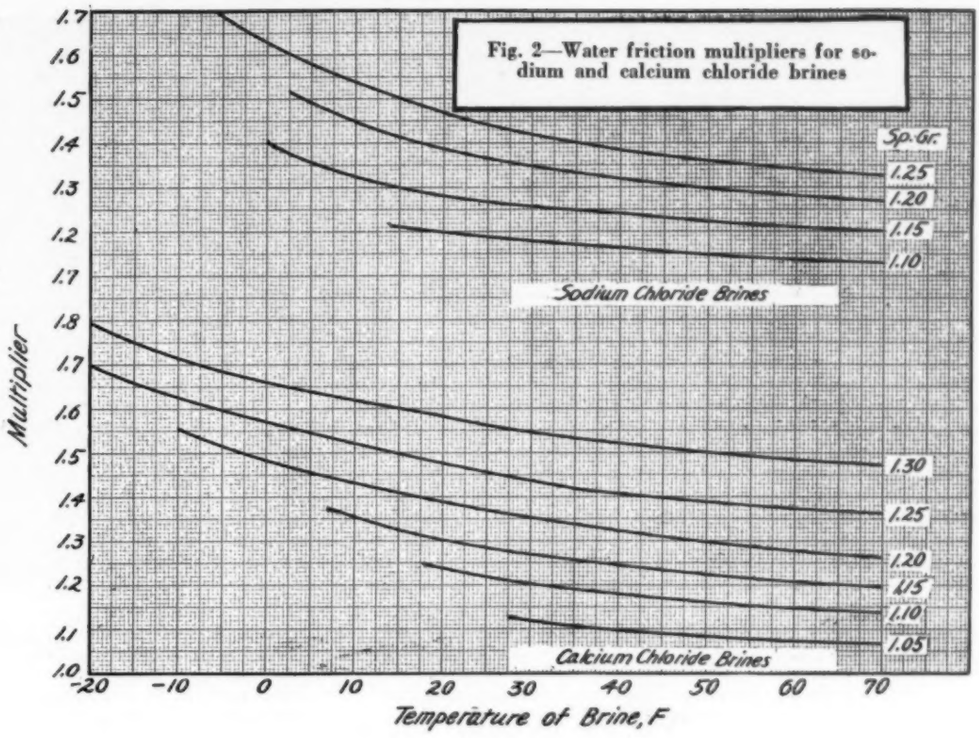



Fig. 2—Water friction multipliers for sodium and calcium chloride brines

A second example indicating the need for the right piping is that of a certain Michigan ice-cream plant originally equipped with four brine-type ice-cream freezers of 80-quart capacity. These were served by a circulation of 100 gpm through 3-in. supply and return mains. Later, increase in business required more freezers and ultimately twenty-two 120-quart freezers were added to the original battery; this naturally required a larger refrigeration load.

The operating engineer calculated the requirements and, inasmuch as he had ample compressor capacity, his only thought was to increase the capacity of the pump. A larger pump was installed, but no other changes made, and it was soon evident that something was amiss, for it required over 30 minutes to freeze one batch, whereas 12 to 13 minutes with this type of freezer should have been sufficient. This not only wasted time and caused consequent loss of production, but over-run was whipped down from 100 to 70 per cent, causing a further loss. A check-up showed the brine mains to be utterly inadequate and a new 6-in. line was proposed.

The engineer did not like the thought of scrapping the 3-in. insulated mains so he installed another 3-in. supply, but no additional return. He said he figured 3 and 3 was 6, but his area was only half that recommended. No noticeable improvement was obtained, inasmuch as he still had two 3-in. supply lines and only one 3-in. return line, "to be sure of getting enough brine over to my freezers and I don't care how it gets back to the cooler." The error was finally corrected by installing 6-in. mains, as at first recommended, which enabled the production to be greatly increased. The batch freezing time was reduced from 32 minutes to 12 minutes and the over-run was controllable by the superintendent, as it should be. This entailed very little expense in comparison with the increased production at a much lower unit cost, and at the same time quality was improved. This is typical of short-sighted piping economy, where remedies can be made that will save the day.

Another instance stresses the same point: A chemical manufacturing plant in Ohio had considerable tonnage capacity for its industrial processes. The plant manager was asked to provide cool drinking water in the office about 600 ft from the plant. The plant pipefitters were dispatched to the job and in a short time two bubblers with ½-in. supply connections were installed. The pipe-fitter figured that it would be unusual for both bubblers to be in use simultaneously and accordingly installed a ½-in. supply and return, making a system involving the equivalent of 1,500 lineal feet of ½-in. line.

It was estimated the load would not be over ½ ton of refrigeration, for the quantity of water recirculated was very small. He installed a small pump, which was inadequate, and later a second and a third, and finally insulated the lines—and still the drinking water was warmer than city tap water. At this point he called for help. It was found that the friction head was so high in this long run of ½-in. pipe line that a 5-hp motor-driven pump was being used and that the heat equivalent of the mechanical work done by the pump in pumping and churning the water was slightly more than the ½-ton cooler capacity, so that the water was actually being heated more than it was cooled. Here is a system that "just grew" like Topsy, but the money spent in material alone far exceeded the money saved in labor by having the plant maintenance crew install a system without benefit of proper design.

If space permitted, many similar examples could be mentioned.

(*To page 69, back Advertising Section*)

**Machinery room of the air-conditioning system designed for storage of refrigerating effect to reduce operating cost. The room is 26 ft by 16 ft by 16 ft high; this view (taken from a point immediately over the condenser and receiver) shows the methyl chloride compressor and the storage tank. At the extreme left is the washer pump. The two small pumps and horizontal cylinder are for circulation and heat interchange for the drinking water system. The vertical cylinder in the left center is the filter for drinking water. Directly above the tank is located a 15,000 cfm supply fan and air washer, complete with auxiliary pump for flooding eliminators. To the front above is located the 10,000 cfm kitchen supply fan, together with its continuous oil filter and heaters**

# *Reduces Air-Conditioning Costs with Compressor-Equipped Plant* Storing Refrigerating Effect

*By* **Charles S. Leopold***

RECENT increase in the use of cake ice in air conditioning has tended to emphasize the well-known fact that there are many possible applications of air conditioning which are rendered inadvisable because of first costs. Frequently it is stated that a plant that does not require refrigeration more than 500 hours a year will be as economical with ice as with mechanical refrigeration, if interest and depreciation and operating costs are all considered. With such cost arguments—particularly at the present time—it is obvious that a prospective purchaser of air conditioning would incline toward the use of ice because of the decreased first cost and the consequent lessened gamble with the factors of changing business conditions and equipment obsolescence.

### Compare Two Types of System on Same Basis

There is no fundamental reason why the results obtained with the use of cake ice should not be entirely equal to the results obtained with mechanical refrigeration. The fact remains, however, that there have been a number of cases where cake ice has been used for refrigeration, and the rest of the air-conditioning job has been done in an inferior manner. Sometimes a job has been sold on the basis of temperature reduction only. Because of the comparatively low first cost, owner acceptance of a mediocre installation has been created. This is most unfortunate as it has exaggerated the difference in cost between ice and mechanical refrigeration. It is not fair to compare the total cost of these jobs, but it is fair to compare the cost of the ice tank and the handling of cake ice with the cost of the mechanical refrigerating unit. If an inferior air distribution and dehumidifier installation is acceptable with ice, there is no reason why it should not be equally acceptable with mechanical refrigeration.

### Careful Analysis Needed

It is only natural that such an apparently simple solution to the problem should be carried to excess and during the past year cake ice has been used as a refrigerant in many plants in which it is not suitable. One example is a small moving picture theater, located in the heart

*Consulting Engineer, Philadelphia, Pa. Member of Board of Consulting and Contributing Editors.

of a metropolitan business section. In warm weather it is necessary that this plant be run to maintain the cooling effect, during the twelve hours the theater is open, merely as a matter of merchandizing and in order to compete with those theaters having mechanical refrigeration. In this latter class of plants the cost of increased hours of use is small, as can readily be seen from the rate structure for electric power. In this city, which has representative rates, the standby charge per kilowatt is $2.00, whereas the charge for energy is 9 mills; for larger users the standby is $1.25 and the energy charge is 8 mills for the first 100 hours' use of the maximum demand and 6 mills for the balance. It is readily seen that extended hours of operation are payable with the 9-mill rate in one case and the 6-mill rate in the other, and that very little economy is to be gained by decreasing the hours of operation.

One large penalty that the mechanical refrigerating unit pays is the fact that refrigeration is needed for only a few days in November and April, which are otherwise non-operating months, and if the plant is used for as little as an hour, the complete standby charge must be paid for the entire month. This item is particularly important with the use of high-velocity air-jet agitating distribution with decreased total air quantities.

### Storing Refrigerating Effect in Compressor Plants

It is also to be noted that mechanical refrigerating machines must be selected to meet the combined and simultaneous peaks of outside temperature, humidity, and occupancy. These conditions are realized comparatively infrequently and during the largest portion of the operating time the compressor is operating at partial load, with decreased efficiency. Obvious answers to this problem are:

Multiple refrigerating units
Water storage tanks

The objection to the former is increased first cost and increased maintenance. The objection to the storage tank is the excessive space required in order to store adequate refrigerating effect in the form of cold water.

In spite of this space condition, there are many reasons in favor of using water storage where possible. By such means compressors can be operated on intermittent control and operate at full efficiency when operating at all. Automatic means of temperature control are considerably simplified and during the periods where a small amount of refrigeration is required, this can be obtained with accurate temperature control, which is difficult with a throttled refrigerating machine.

### Restaurant Plant Stores Ice, Cuts Peak Load

We have recently designed a storage system which illustrates this point. It indicates that mechanical refrigeration can be properly engineered to fit the job with short operating hours and produce over-all operating costs below a comparable system using cake ice. This system has been in operation for more than a year and accurate costs are available.

Briefly, the problem was to cool a restaurant which serves lunch only; restaurant has 400 seats and serves over 2000 meals daily. It is located in the basement of a large office building and has an entrance from an open stairway which runs the height of the building. For this reason an unusual amount of fresh air is used.

In addition, it was decided to carry a very low dew-point to permit of obtaining comfort at a comparatively high temperature. Although we all realize the desirability of such design, very few jobs have been designed on this basis because of the increased factors of cost introduced by low evaporator temperatures and additional reheating by steam. As will be shown, both the low temperature and the increased cost of refrigeration in the storage type of job are so small that this design is easily justified.

The problem worked out with a 55-ton peak capacity, with spray water entering the washer at 40 F, which would necessitate an evaporator temperature of approximately 28 F. The storage type of job, as actually installed, makes use of a compressor of 8.65 tons at an evaporator temperature of approximately 15 F. The storage tank occupies a space 6′x6′x20′ and is so arranged that the system can store six tons of ice in eighteen hours, the six-hour margin of safety (24 hours minus 18 hours) being allowed for certain engineering contingencies which had never been adequately investigated, and to permit of occasional stopping of the compressor to prevent coincidence of electrical load peaks. The plant is entirely automatic in operation, requiring no more attention than a full automatic refrigerating machine attached to a water-storage tank, and less attention than a direct operating unit. The ice is, of course, not handled in any way. It forms on coils in definite channels during the period it is built up and is melted down by the water returning from the dehumidifier.

It may be noted that the restaurant has a very similar refrigerating problem in the use of drinking water, as large quantities are used by the patrons during the hours the restaurant is open. It was therefore apparent that a means of combining this ice-water load with a storage tank would be desirable and a heat interchanger with a small circulating pump was installed to meet this condition.

### Cost Comparison of Compressor Ice-Storage Plant

For the purpose of cost comparison, we will consider only the first cost and operation of the refrigerating machine as compared with the use of ice. The fans and associated apparatus are common to both systems.

Complete installation of refrigerating equipment, including storage tank and compressor, cost approximately $5,000. The installation of a suitable ice tank for similar duty would be not less than $1,000. The actual yearly operating cost of the mechanical plant as determined by the difference in power and water bills between summer and winter operation is as follows:

| | | |
|---|---|---|
| First cost, $5,000 | | |
| Amortization and interest (10 yrs. @ 14%) | 700 | |
| Power and water | 446 | |
| Supplies | 150 | $1,296 |

(*To page 74, back Advertising Section*)

# *The* FLOW *of* FLUIDS *in* PIPES

***Flow of Incompressible Fluids in Pipes—Part II of a Series. Part I (published last month) Reviewed the Data Available. Future Articles will Cover Flow of Compressible Fluids; Losses from Enlargements, Contractions, and Fittings; Economical Design of Process Piping . . . . . By Emory Kemler****

ONLY within the last few years have industrial fluids been piped on a large scale; for this reason it is to be expected that one cannot find data on which to make pressure-drop calculations for many of them. Most of the experimental work on the flow of fluids has been done with water, because of the ease and cheapness of making the experiments and because it is the one that is most piped. The method of analysis using Reynolds' number makes it possible to use data found for water to solve problems involving other fluids. It is possible therefore to make pressure-drop calculations for a fluid that has never been piped before with the same accuracy as for water, other conditions being equal.

If the pipe length, volume of flow, pipe size, viscosity and density of the fluid flowing are known, it remains only to find the friction factor. The difference between the method of analysis using Reynolds' number and the empirical formulas is in the nature by which the friction factor $f$ is determined. The empirical formulas of Darcy, Williams-Hazen, Weymouth, Chezy, etc., do not take into account all of the variables. They neglect the effect of viscosity and density of the fluid and in some cases the effect of velocity and pipe diameter on the friction factor. Hazen and Williams, for instance, use a coefficient for brass pipe that is higher than for cast-iron pipe in order to make the formula check with practice. It is quite obvious that brass pipe is not rougher than cast-iron pipe, but this is the absurd thing often necessary to make empirical formulas cover the wide range of conditions met in practice.

It is not intended to convey the idea that these empirical formulas cannot be applied to some engineering problems or that they do not give reliable results. If they are based on accurately-taken experimental data, they will hold for the range of conditions covered in the experiments, and for these conditions *can be made* as accurate as any other formula. If the formula is used for conditions outside the limits covered by the experiments the results will not always be reliable.

To obtain a general empirical formula for even one fluid and one kind, size, and condition of pipe it is necessary to run a series of tests to cover the velocity range needed at not one but a series of temperatures to cover the entire range of conditions encountered in practice. The difficulty of obtaining accurate empirical formulas can be appreciated when one considers that this procedure must be repeated for each size, kind and condition of pipe and for each fluid to be considered.

* Engineering Division, Gulf Research Laboratory, and Instructor in Mechanical Engineering, University of Pittsburgh, Pittsburgh, Pa.

### Pressure Drop in a Pipe

The pressure drop in a pipe is made up of the drop due to flow, losses due to sudden enlargements or contractions, losses in making turns or in going around bends, and losses in going through fittings.

The formula used to determine the pressure drop of an *incompressible* fluid flowing in a circular pipe is:

$$\Delta p = \rho \, \Delta h = \frac{f l v^2 \rho}{2g D \times 144} = \frac{8 f l V^2 \rho}{g \pi^2 D^5 \times 144} = \frac{8 f l W^2}{g \pi^2 D^5 \rho \times 144}$$

$$= \frac{8 f l Q^2 \rho}{g \pi^2 \times D^5 \times 144 \times 56}$$

$$= 0.00129 \frac{f l v^2 \rho}{d} = 43.76 \frac{f l V^2 \rho}{d^5}$$

$$= 43.76 \frac{f l W^2}{d^5 \rho} = 0.78 \frac{f l Q^2 \rho}{d^5}$$

*where* $\Delta p$ = pressure drop in lb per sq in.
$\Delta h$ = pressure loss in feet of liquid
$l$ = length of pipe in feet
$g$ = acceleration of gravity = 32.2
$D$ = pipe diameter in feet
$d$ = pipe diameter in inches
$v$ = mean velocity of flow in feet per second
$W$ = rate of flow in pounds per second
$V$ = rate of flow in cu ft per second
$Q$ = rate of flow in gallons per second
$\mu$ = absolute viscosity in lb/ft × sec
$\rho$ = density in lb per cu ft
$f$ = friction factor

### Viscosity of the Fluid

In order to use Reynolds' method of analysis it is necessary to have data on viscosities; Fig. 1 gives such data for a number of fluids. The data for most of these were taken from the "Handbook of Physics and Chemistry" and the Smithsonian tables. Information on a number

of other fluids is also given in these books. The data on brine were taken from the University of Illinois Engineering Experiment Station Bulletin 182 on "Flow of Brine in Pipes," by R. E. Gould. The data on the viscosity of gasoline were taken from *The Pipe Line News*. Data on viscosities of uncommon fluids can frequently be found by looking up articles listed in "Chemical Abstracts."

The viscosity of oil and the other more viscous fluids is ordinarily obtained with a Saybolt viscosimeter. If the results for oil are plotted on the standard *A. S. T. M.* temperature-viscosity chart the temperature-viscosity curve is a straight line within wide ranges. A curve for a typical lubricating oil plotted on the *A. S. T. M.* chart is shown in Fig. 2. It will be noted that for a particular viscosity in Saybolt seconds there exists a definite value of kinematic viscosity which is expressed in c.g.s. (centimeter-gram-second) units as stokes or centi-stokes (1 stoke = 100 centi-stokes) on the chart. To obtain absolute viscosity in f.p.s. (foot-pound-second) units, multiply the stokes by the specific gravity and by the factor 0.0672.

Absolute viscosity in f.p.s. units = kinematic viscosity in c.g.s units (stokes) × specific gravity × 0.0672.

Absolute viscosity in f.p.s. units = absolute viscosity in c.g.s. units (poises) × 0.0672.

The absolute viscosity in f.p.s. units is also given by absolute

$$\text{viscosity} = \text{specific gravity} \times \left[0.000148\,t - \frac{0.120}{t}\right] \times 0.0672$$

where $t$ = viscosity with a Saybolt viscosimeter in seconds.

### Three Types of Flow Problems

These data and the friction factor curves in Figs. 1 and 2 of my previous article[1] give the data necessary to solve flow problems in new or clean steel pipes. There are three general types of problems that arise. The first is where the length and diameter of the pipe, and the properties and quantity of fluid flowing, are known. The problem is to calculate the pressure drop.

*Example:* As an example, assume it is desired to calculate the pressure drop in a 2-in. standard pipe 100 ft long carrying 0.1 cu ft of water per second at 70 F.

The procedure is first to find the Reynolds' number and from the friction factor curves given in Figs. 1 and 2 of the previous article[1] to find the friction factor $f$ and then substitute the values in the equation for pressure drop.

The Reynolds' number is:

$$R = \frac{D v \rho}{\mu} = \frac{4}{\pi}\frac{V \rho}{D \mu} = 15.3\frac{V \rho}{d \mu} = 15.3\frac{W}{d \mu} = 2.04\frac{Q \rho}{d \mu}$$

For this case $\mu = 6.5 \times 10^{-4}$ (from Fig. 1 of *this* article).
$\rho = 62.4$ lb per cu ft
$d = 2.07$ in.

$$R = 15.3 \times \frac{0.1 \times 62.4}{2.07 \times 6.5 \times 10^{-4}} = 71{,}000 = 7.1 \times 10^4$$

From Fig. 2 of the *previous* article $f = 0.023$

$$\Delta p = 43.76 \times \frac{0.023 \times 100 \times (0.1)^2 \times 62.4}{(2.07)^5} = 1.66 \text{ lb per sq in.}$$

The second type of problem is to find the quantity that can flow with a certain allowable pressure drop. This type of problem cannot easily be solved directly, since $f$ depends upon the volume or velocity of flow and this complicates the solution. The problem can be solved only by trial and error, unless $f$ be expressed in terms of the Reynolds' number. It is usually necessary only to solve for two rates of flow, as the following example shows.

*Example:* Assume that it is desired to know the volume of flow to give a pressure drop of 5 lb per sq in. per 100 ft of 1-in. standard pipe carrying gasoline at 60 F having a density of 56 A. P. I., which corresponds to a specific gravity of 0.75 and a density of 46.8 lb per cu ft. If we try a flow of 0.05 cu ft per second we can find the pressure drop exactly as in the previous example:

$\mu = 4.3 \times 10^{-4}$ (from Fig. 1)
$d = 1.05$ in.

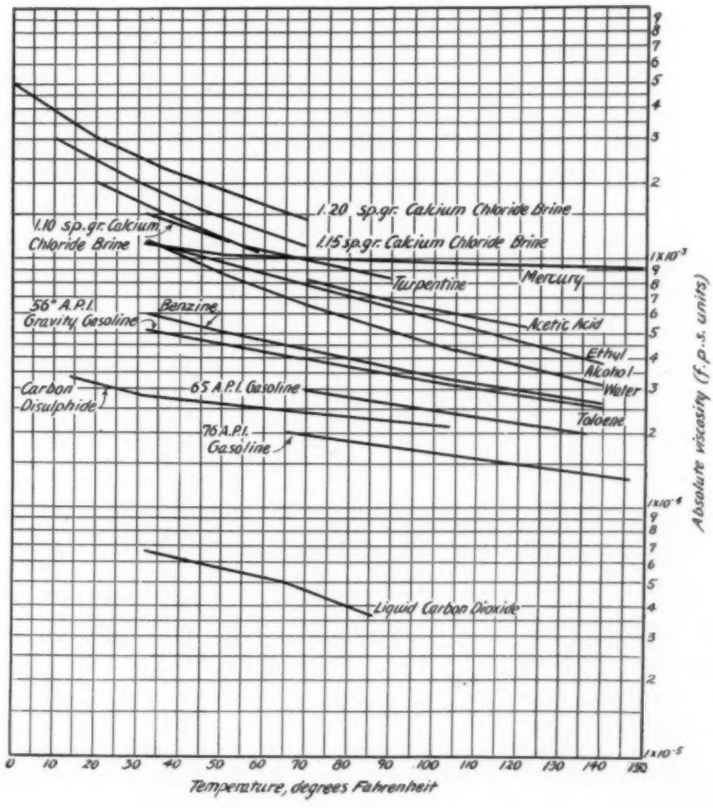



Fig. 1—Viscosities of several typical fluids which are piped

[1] "The Flow of Fluids in Pipes," by Emory Kemler. HEATING, PIPING AND AIR CONDITIONING, May, 1933, p. 252. (Abstracted from a paper presented at the annual meeting of the *A. S. M. E.*, December, 1932.)

$$R = 15.3 \times \frac{0.05 \times 46.8}{1.05 \times 4.3 \times 10^{-4}} = 7.50 \times 10^4$$

From Fig. 2 of the previous article $f = 0.026$

$$\Delta p = 43.76 \times \frac{0.026 \times 100 \times (0.05)^2 \times 46.8}{(1.05)^5} = 10.5 \text{ lb per sq in.}$$

This volume of flow is too high as it gives too high a pressure drop. If we now assume a quantity of flow $V = 0.02$ cu ft per second:

$$R = 15.3 \times \frac{0.02 \times 46.8}{1.05 \times 4.3 \times 10^{-4}} = 3 \times 10^4$$

This value of $R$ gives $f = 0.028$

$$\Delta p = 43.76 \frac{0.028 \times 100 \times (0.02)^2 \times 46.8}{(1.05)^5} = 1.81 \text{ lb per sq in.}$$

This value is too low. If we should plot $\Delta p$ against $V$ on log-log paper the result will be an approximate straight line. If the range extends above and below the critical velocity more than two points must be taken. The values are shown in Fig. 3. The value of $\Delta p = 5$ lb per sq in. corresponds to a value of $V = 0.034$ cu ft per second.

The third type of problem is to find the pipe diameter when the volume of flow and allowable pressure drop are given. The procedure is the same as in the previous example.

In last month's article it was mentioned that if the flow was streamline the pressure drop would be given by:

$$\Delta p = \frac{64 \mu l v}{2 g D^2 \times 144} = 184 \frac{\mu l V}{d^4}$$

This formula applies if Reynolds' number does not exceed 2000. When Reynolds' number exceeds 2000 the equations for turbulent flow should be used for determining the pressure drop.

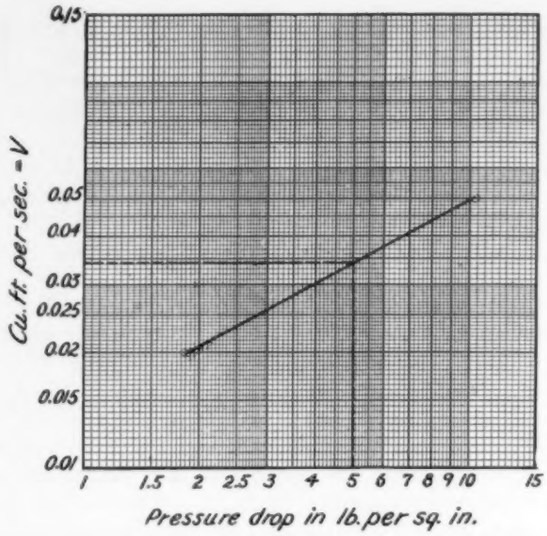



**Fig. 3—Curve showing relation between "pressure drop" and "cubic feet per second" for example given on this page**

*Example:* Consider as an example that it is desired to find the *differential* pressure necessary to cause 0.01 cu ft of oil (at 50 F, having a specific gravity of 0.9 and the viscosity shown in Fig. 2) to flow through a 1-in. standard pipe 100 ft long per second.

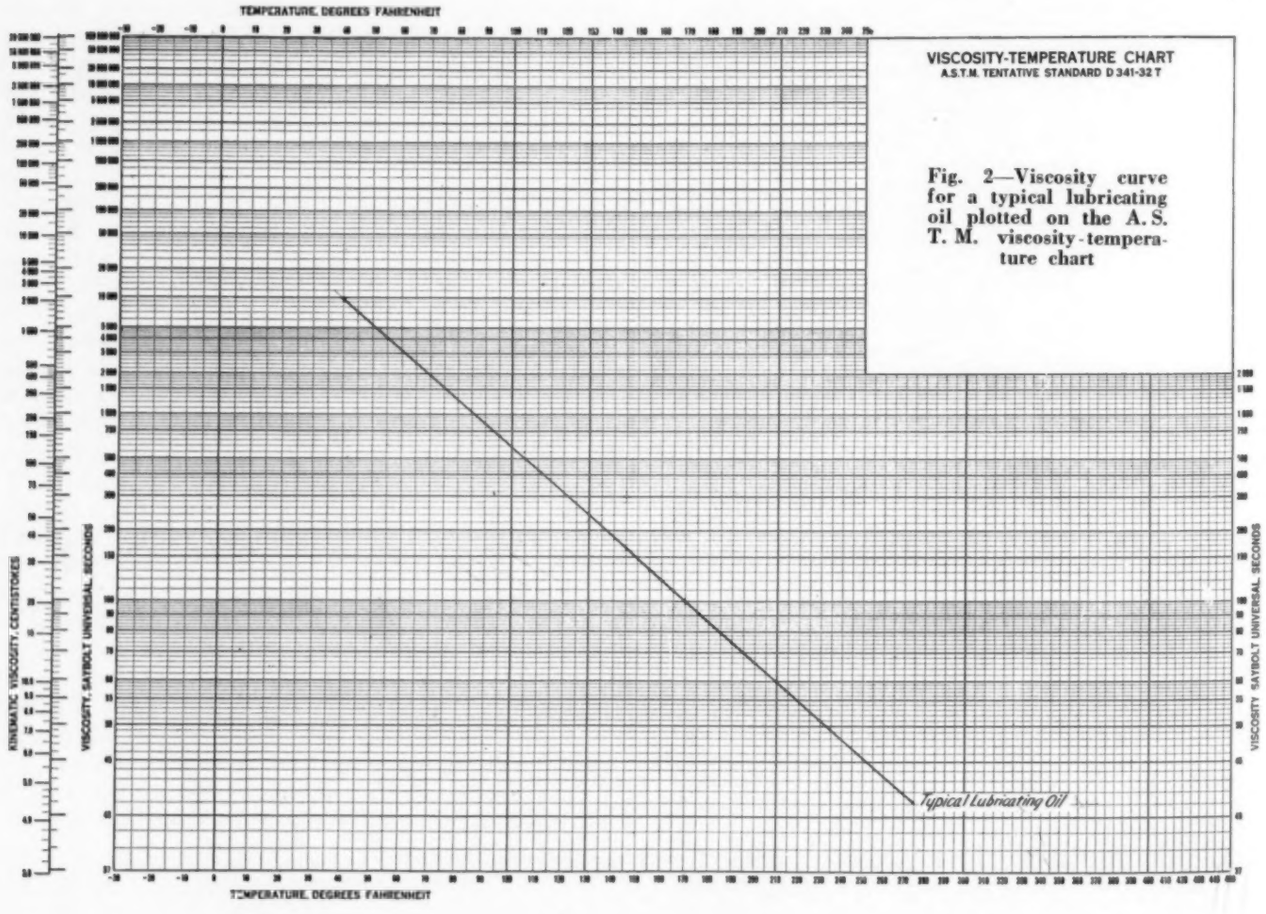



**Fig. 2—Viscosity curve for a typical lubricating oil plotted on the A. S. T. M. viscosity-temperature chart**

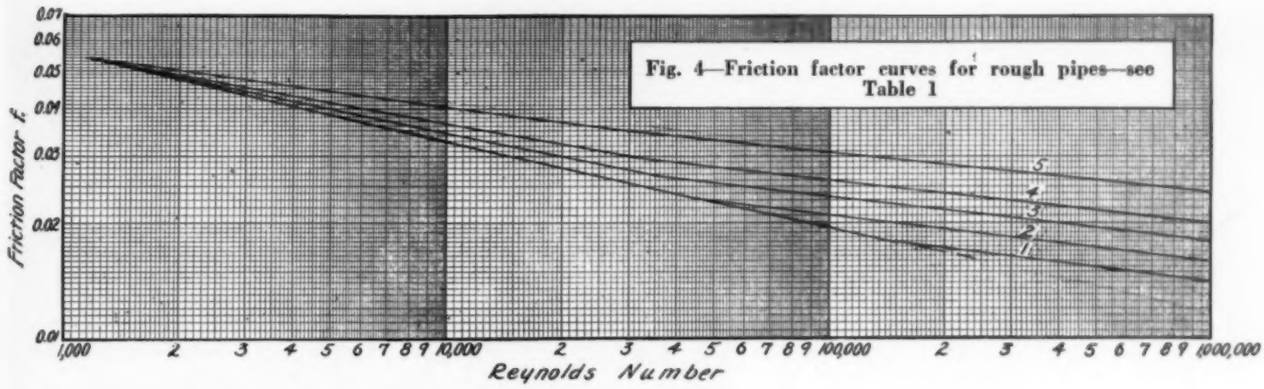



Fig. 4—Friction factor curves for rough pipes—see Table 1

**Table 1—Sizes and kinds of pipe to which curves in Fig. 4 apply**

*Pipe Sizes in Inches*

| Curve No. (See Fig. 4) | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Galvanized | 30 | 6-8 | 2½ | 1¼ | ¾ |
| Good C. I. and concrete / Light riveted sheet ducts | 96-48 | 16-12 | 4-3 | 1½ | 1 |
| Ave. C. I. / Rough formed concrete | 96 | 36-24 | 8-6 | 3 | 2 |
| Good Brick / Heavy Riveted Pipe | 220 | 72-48 | 18-16 | 8 | 4 |

From Fig. 2 the kinematic viscosity is 1200 centistokes or 12 stokes.

The absolute viscosity in f.p.s. units is given by:

$$\mu = 12 \times 0.9 \times 0.0672 = 0.726$$

$$R = 15.3 \times \frac{0.01 \times (0.9 \times 62.4)}{1.05 \times 0.726} = 11.3$$ so that the pressure drop can be calculated from:

$$\Delta p = 184 \times \frac{0.726 \times 100 \times 0.01}{(1.04)^4} = 110 \text{ lb per sq in.}$$

It will be noted that when this oil is heated to about 245 F the flow will be turbulent as the viscosity will have been reduced to 1/200 of its value at 50 F. In this case $R = 2260$.

## Establishing the Friction Factor for Different Pipes

These data give all the information necessary to calculate the pressure drop in new or clean steel pipes. It still remains to establish the values of friction factor to be used for other types of pipes. A summary of the data on galvanized, used steel, cast-iron, tar-coated, riveted and cement pipes was given in the author's paper presented at the annual meeting of the *A. S. M. E.* in New York City last December. Pigott[2] has analyzed the problem on the basis of roughness and has drawn curves based on the summary mentioned. An abstract from his curves is shown in Fig. 4 and the sizes and kind of pipe to which these apply are given in Table 1. On the basis of these data the pressure drop can be determined for any type and kind of pipe.

*Example:* As an example, consider that it is desired to know the pressure drop per 100 ft for a 1.20 calcium chloride brine at 60 F flowing through a 1½-in. standard galvanized pipe at the rate of 30 gallons per minute:

$$R = 2.04 \times \frac{62.4 \times 1.20 \times (30 \div 60)}{1.61 \times 1.3 \times 10^{-3}} = 36{,}700$$

From Table 1 we see that Curve 4 of Fig. 4 should be used to determine $f$. The value of $f$ as found then is 0.029.

[2] "Flow of Fluids in Closed Conduits," by R. J. S. Pigott, a paper presented at the June, 1932, *A. S. M. E.* Process Meeting, at Buffalo, N. Y.

$$\Delta p = 0.78 \times \frac{0.029 \times 100 \times (30 \div 60)^2 \times 1.2 \times 62.4}{(1.61)^5} = 3.75 \text{ lb per sq in.}$$

In the case of used pipe where corrosion or accumulations on the pipe surface take place, the safest way to calculate the pressure drop after it has been in operation is to estimate the ultimate diameter and use a value of $f = 0.054$. The reason for this was shown in the article last month.

## When Pipe Is Not Circular

The equations given in these articles have been for circular pipes. Often it is necessary to make calculations for non-circular sections, annular sections, and sections with a free surface. In order to handle such sections a term called the mean hydraulic radius has been devised. This term is based on supposition that the resistance for pipes having the same area is proportional to the fluid in contact with the pipe surface. If we represent this mean hydraulic radius by $r$, we have

$$r = \frac{\text{area of cross section}}{\text{wetted perimeter}}$$

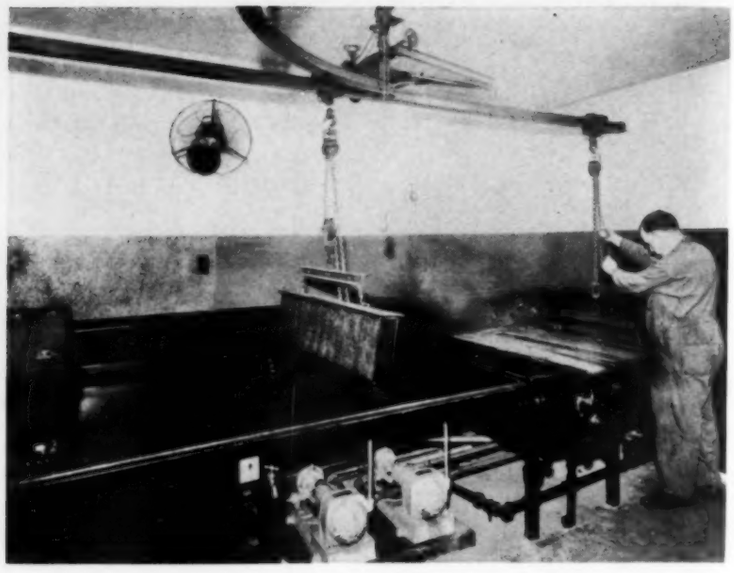
The equivalent diameter of a circular pipe is $4r$, or four times the mean hydraulic radius. Experimental data show that there is little error for ordinary shapes in using this mean hydraulic radius for turbulent flow. There is, however, a large error for viscous flow for these annular or rectangular sections. A study of the data on turbulent flow through annular spaces being made at the University of Pittsburgh by K. Peters indicates that the friction loss in annular spaces is higher than the value that would be given by using the equivalent diameter.

---

The revised simplified practice recommendation *R57-32*, covering wrought-iron and wrought-steel pipe, valves and fittings is now available in printed form, and copies can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 5 cents each, according to the division of simplified practice of the *Bureau of Standards*.

The revision, as proposed and formulated by the industry, eliminates the 3½-in. nominal inside diameter pipe from Table 3, "Double Extra-Strong" pipe, which was included in the original recommendation. This simplification program has been instrumental in reducing the number of stock sizes of pipe from 62 to 48, and in effecting a corresponding reduction in the variety of sizes of valves and fittings.

*By* W. H. Junker*



# Servicing *the* Air Filters *for* 140 Unit Ventilators

SERVICING of the large number of air filters which annually keep more than a ton[1] of atmospheric soot and dirt from entering the Cincinnati & Suburban Bell Telephone Company building, Cincinnati, Ohio, has been simplified greatly by the automatic filter cleaning equipment designed by the author to provide a practical and efficient method for handling, cleaning, charging and storing the filters.

[1]Atmospheric dust consists of microscopic particles of soot, sand, ashes, metal, fiber, chemicals, animal and vegetable matter and many other types of disintegrated matter, together with bacteria, mold spores, pollens, and other micro-organisms.

The average dust analysis of a coal-burning industrial city of varied manufacturing plants will fall within the following analysis:

| | |
|---|---|
| Smoke carbon (soot) | 44 -48 % |
| Siliceous matter | 40 -45 % |
| Coal dust | 2½- 3½ % |
| Fibrous matter | 3 - 5 % |
| Miscellaneous | 5 - 8 % |

The average monthly soot fall per square mile in downtown Cincinnati for 18 months in 1931 and 1932 as recorded by the smoke department of the city is 70 tons on the 48th floor (base of flag pole) of the Carew tower and 99 tons on the roof (18th floor, of the Ingalls building. These values are somewhat lower than that reported by the Mellon Institute several years ago, due possibly to the higher elevations where our data were obtained and also to improvement (12% in 1929) in the clearing of the Cincinnati atmosphere through law enforcement. There are approximately 15,000 dust particles per cu ft of air in Cincinnati or about 0.6 grains (437.5 grains equal one ounce) per 100 cu ft. In order to realize fully the enormous cumulative effect of a dust concentration of even such a low value, let it be assumed that only a half of the unit ventilators that are installed in the building are operating on second speed, without the use of some means of air filtration. On this basis there would be introduced 1.6 tons of atmospheric soot and dirt into the building annually. With oil-impregnated filters at the intakes of the unit ventilators, only 100 lb. of atmospheric dust will enter the building annually.

*Mechanical Engineer on the Staff of Harry Hake, Architect, Cincinnati, Ohio.

### 140 Units Ventilate Building

The entire building (with the exception of the subgrade portion) is ventilated by 140 unit ventilators distributed throughout the upper floors supplying filtered and tempered air to the various equipment rooms, operating rooms, offices, etc. Central exhaust fans are operated in step with the air supply to maintain constantly a slight pressure in the building, as all windows are locked shut. Each unit ventilator is equipped with three-speed control, delivering 800 to 1200 cfm of air. The filter used is of the drawer type located horizontally and at the bottom of the ventilating unit; it is of the adhesive-impingement type, packed with metallic filter media 4 in. thick saturated with oil.

### Filter-Cleaning Equipment Essential

The servicing of such a large quantity of filters would present a difficult problem unless some means of automatic cleaning was provided. Cleaning methods ordinarily in use were not considered desirable for this installation for several reasons:

The filter weight of 48 lb and the dimensions (4″x12″x46″) present a problem in handling and moving the filter through the cleaning bath.

The finished edge that matches the unit ventilator cabinet cannot be immersed in cleaning solutions due

**Fig. 1 (at top)—Filter-cleaning room in the Cincinnati & Suburban Bell Telephone Company building, showing the equipment to clean and recharge the filters of the 140 unit ventilators installed throughout the building**

to the chemical action upon the enamel.

The cleaning should be as nearly automatic as practical to minimize labor involved.

The cleaning equipment is an essential auxiliary to the ventilating system of the building and great care was taken in its design.

### How the Filters Are Serviced

Dirty filters are brought into the filter-cleaning room by a small double-deck truck having a capacity of eight filters. They are elevated and conveyed to the cleaning solution compartment by means of a carrier traveling on a tram rail. The filter is lowered into this tank, which is filled with a solution of hot water and cleaning powder, with the clean side (facing up in unit ventilator) towards the pipe grid. After the filter is in place, the operator starts the circulating pump, which, through the jet action of the pipe grid, moves the cleaning solution through the filter media, thereby cleaning it of all foreign matter, dirt and oil. This operation requires about 10 minutes.

The filter is then moved to the adjacent compartment, which is filled with clean hot water and is also equipped with a pipe grid and a circulating pump similar to the cleaning compartment. After the filter is in position, the pump is operated for a few minutes, rinsing the filter of all cleaning solution. Each of these compartments is provided with a steam-pipe-

(*To page 68, back Advertising Section*)

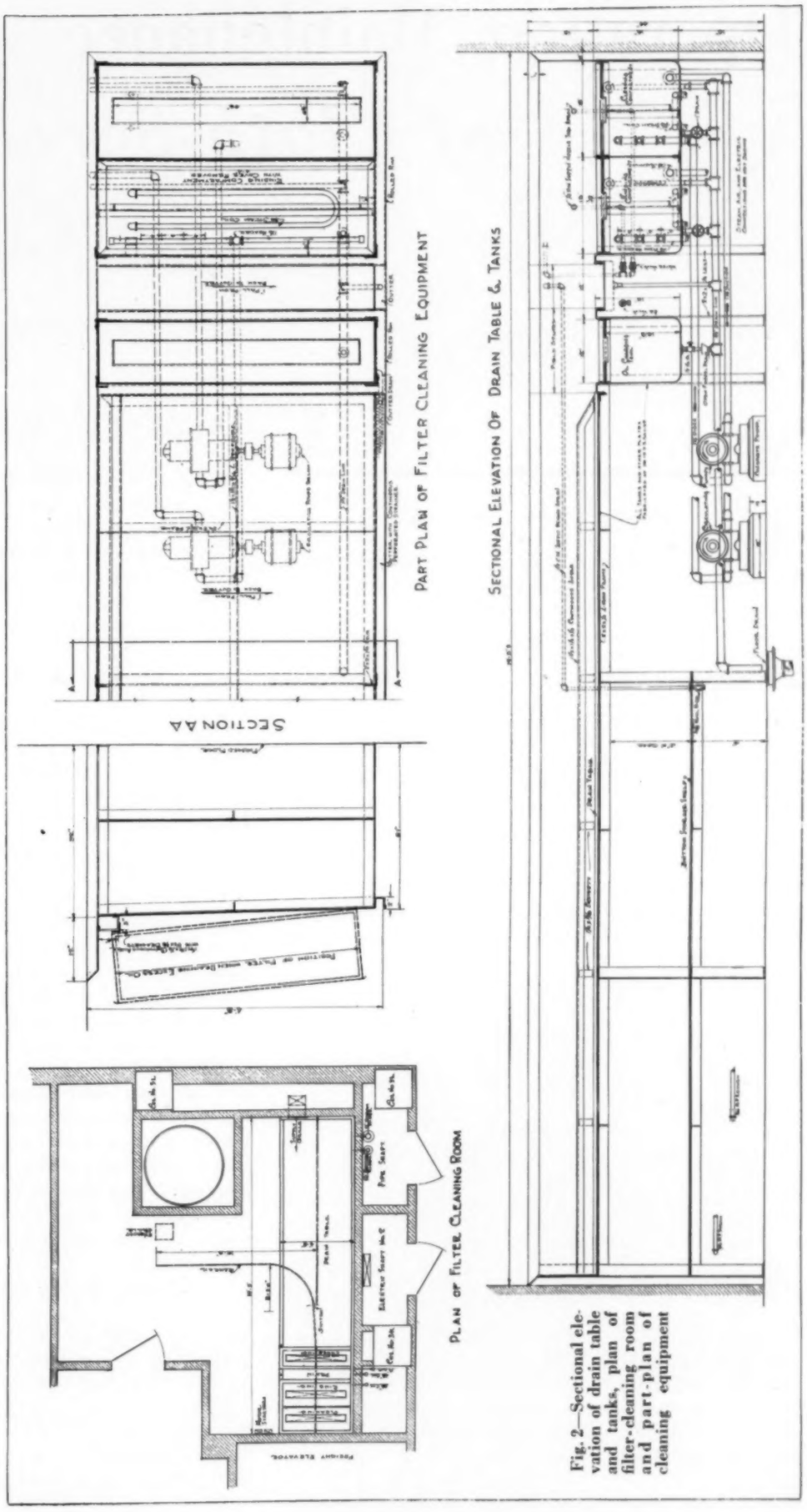

SECTION A-A
PART PLAN OF FILTER CLEANING EQUIPMENT
SECTIONAL ELEVATION OF DRAIN TABLE & TANKS
PLAN OF FILTER CLEANING ROOM

Fig. 2—Sectional elevation of drain table and tanks, plan of filter-cleaning room and part-plan of cleaning equipment

# Operation, Maintenance *of Cloth-Screen* Dust Collectors

By W. F. Terry*

LAST month the construction and operation of a cloth-screen type industrial dust-collection system was described briefly and a number of maintenance pointers were given, including a proposed method for controlling the rapping of the screens. In the present article the information on operation and maintenance is completed.

### Maintenance of the Arrester Case

As was mentioned last month, the dust-arrester case should be as nearly air-tight as possible and kept so at all times to avoid troubles due to air and water leaks. In addition, it should be painted frequently to prevent rusting. If the dust arrester is located near the power plant, cinders are likely to accumulate on the roof; when mixed with moisture they form sulphuric acid which soon eats holes in the case.[1] The platform around the case should not be placed too close to the sides, but kept back two or three inches to allow snow and ice to melt and run off and prevent the sides and bottom of the steel case from rusting. Spaces also should be left between the platform boards to allow for drainage.

Wear on the inside of the case at top or side, due to the abrasive action of the dust as it leaves the suction pipe and rebounds after hitting the baffle plate, especially where this pipe enters the case near a corner, may be prevented by additional liner plates on the inside of the case at these points. The case itself should be sufficiently reinforced to withstand the suction pressure to which it is subjected and thus prevent the whipping action which may produce leaks in a poorly-designed case.

### Design Piping for Easy Maintenance

Piping maintenance can be greatly reduced if the following points are observed in the original design:

(*To page 76, back Advertising Section*)

### A Schedule for Inspection

Inspections constitute the best preventive maintenance known and should be made at least twice monthly. They should cover the following points:

1. Rapping device, including motor drive, gears, and lubrication.
2. Condition of screens, and leaks: Do they have appearance of being rapped regularly?
3. Do hoppers need emptying?
4. Condition of hoppers and hopper valves: Are they tight, leaking, or out of order?
5. Chutes: Are they missing from hoppers?
6. Baffle plates: Are they secure?
7. Dust arrester doors: Are they leaking?
8. Leaks in clean-air side of arrester.
9. Fan: Check speed, general cleanliness, and lubrication; also motor.
10. Condition of walk lights, platform, toe boards, and ladders.
11. Ventilating pipe, leaks, check clean-out to see if pipe is filling up.

Inspector and repair men should remove fuses, pull switches, and lock switch boxes on fans and rapping devices before entering dust arrester for inspection and should wear approved respirators and goggles while inside the arrester. For their convenience electric outlets should be installed along the platform and the men provided with an extension cord and light. They should have complete authority to shut down the entire apparatus at such times as inspection is required after reporting to the foreman, and minor troubles should be repaired at the time inspection is made. Their reports, in triplicate, should be signed and dated, one copy kept for their own file, the second sent to the superintendent of the department responsible for this equipment, and the third copy to some man appointed by the general superintendent of the plant to have charge of dust collection, and whose duty it should be to keep in touch with existing conditions, see that defects reported are corrected promptly, and make necessary arrangements with production departments for major repairs and replacements involving shutdowns.

*Department of Industrial Hygiene, Harvard School of Public Health, Boston, Mass. Formerly Field Inspector, Plant Engineering Department, General Electric Company.

[1] "Air Pollution from the Engineer's Standpoint," by H. B. Meller. Presented at the 37th Annual Meeting of the *American Society of Heating and Ventilating Engineers* and published in HEATING, PIPING AND AIR CONDITIONING, January, 1931, page 70.

**Building for the National Archives, Washington, D. C. An air-conditioning system handling 330,000 cfm will aid in the preservation of valuable government records and documents**
John Russell Pope, Architect

# New National Archives Building Conditioned to Protect Records

IN planning the National Archives Building, now under construction in Washington, every reasonable precaution is being included for the preservation of valuable Government records, according to the Bureau of Standards.[1] At present there is no general depository for the records, and they are scattered through many buildings, exposed variously to danger of loss by fire, theft, and deteriorative influences.

In addition to the usual protective measures against loss through fire and other visible and well-recognized enemies, unusual precautions have been taken to guard against insidious enemies of paper and bindings, such as light, and air not properly tempered and purified. In planning the defense against such deteriorants of records, the recommendations of the Bureau of Standards were followed. These are based upon an extensive study of the preservation of records in libraries conducted by the bureau with the assistance of funds granted by the Carnegie Foundation to the National Research Council.

While it has been generally known that light is not favorable to the preservation of paper, the bureau has shown that its destructive effect is more rapid and intense than commonly appreciated. In the Archives Building daylight will be entirely excluded from the storage spaces; small incandescent bulbs, turned on only as needed, will supply the necessary illumination.

### Air-Treating System Handles 330,000 cfm

A large air-treating system capable of handling 330,000 cubic feet of air per minute will insure the purity and proper tempering of the atmosphere throughout the building. A feature will be the washing of the air with an alkaline solution to remove positively any acidic contamination which might otherwise find its way into the storage space. The bureau's work has shown that acid gases, especially sulphur dioxide, widely produced by the combustion of fuels, accelerate the deterioration of all kinds of papers. The temperature and moisture content of the air will be carefully controlled, for high temperature and extreme dryness promote embrittling of paper, while too much moisture may cause molding. It is planned to maintain a relative humidity of 55 per cent in the storage spaces and of 45 per cent in the workrooms. The latter condition is better adapted to human beings. The temperature throughout will be kept at 70 F during the winter and 80 F during the summer. The higher temperature during hot weather is more economical, and is more healthful for the personnel, as it avoids sudden exposure to too great a change in temperature in entering or leaving the building. Continuous maintenance of the humidity within 2.5 per cent and of the temperature within 1 F above or below the chosen conditions is believed feasible.

Another interesting precaution is the use of glazed tile and the incasing of concrete columns in nonferrous metal to minimize abrasive dust. Coated or nonferrous metals will be used where metal is required in the storage spaces, to eliminate the necessity of repainting, which would be hazardous to the stored records.

This archives building can well serve as a model for the housing of valuable records of all kinds, since in planning it advantage has been taken of advanced architectural, engineering, and scientific knowledge.

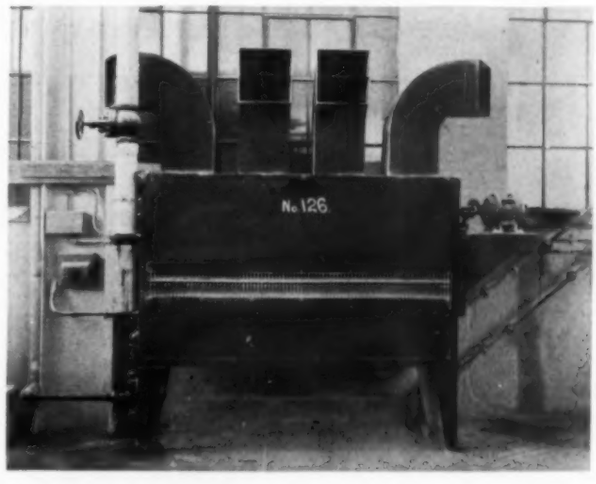
[1] *Technical News Bulletin*, Bureau of Standards, No. 190, February, 1933.

# Effect of Water and Oil on Natural Cork Discussed

I HAVE read with interest the article by Samuel R. Lewis "Noise in Heating and Air Conditioning" in the April, 1933, HEATING, PIPING AND AIR CONDITIONING.

As isolation engineers, we appreciate the very com-

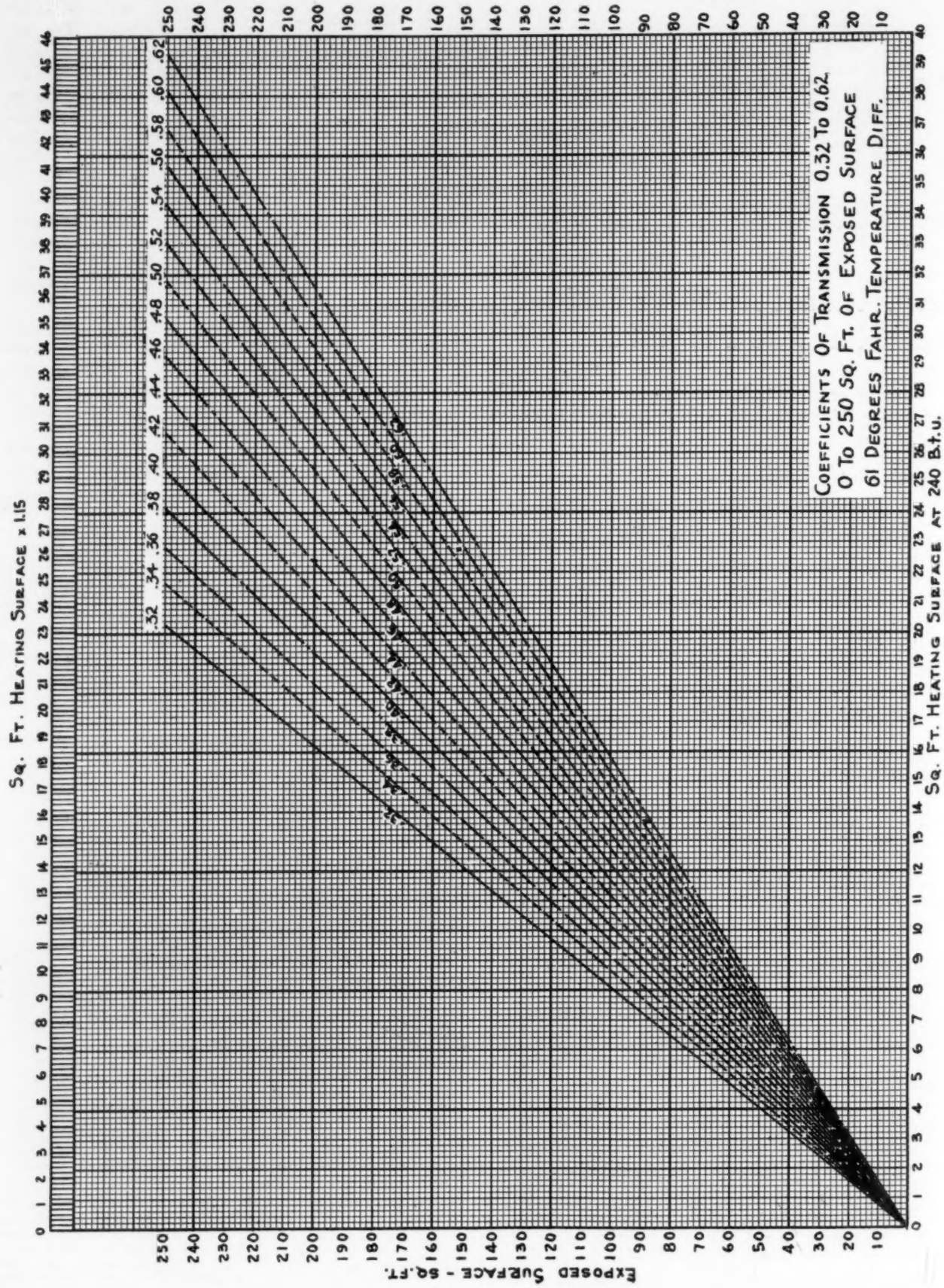
(*To page 73, back Advertising Section*)




**One of the four units which heat the recently-completed outside finishing shop of the Vermont Marble Company, Proctor, Vt., where highly skilled machine work is done. Two units are placed along the walls at each end of the 200 by 300 ft shop. The thermostatic control for each heater is located near the center of the shop**

# Calculating Heating Surface for Buildings . . . . . 3

. . . . by Price L. Rogers, Consulting Engineer, Philadelphia, Pa. This is Chart No. 3 of a series designed to enable computations for heat losses from buildings to be made accurately, with a minimum of time and with decreased possibility of errors. Chart No. 1 and an explanation of the series and its use was published in April; Chart No. 2, last month.


Coefficients Of Transmission 0.32 To 0.62
0 To 250 Sq. Ft. Of Exposed Surface
61 Degrees Fahr. Temperature Diff.
Sq. Ft. Heating Surface x 1.15
Exposed Surface - Sq. Ft.
Sq. Ft. Heating Surface at 240 B.t.u.

# *INTERESTING*
# Equipment.....
# Developments

## New Breakers

A complete line of small circuit breakers, rated up to 600 volts and 600 amperes, and designed for the control and protection of industrial and other circuits has been announced by the General Electric Company, Schenectady, N. Y. They employ a unique principle of arc interruption, operate quietly and permit no external arc. The interruption takes place within a closed metal chamber. When an overcurrent trips the breaker, the contacts are disengaged within the metal chamber. The arc, which is drawn between the contacts, generates a pressure which increases the resistance of the arc path so rapidly that the circuit is interrupted in 0.008 of a second.

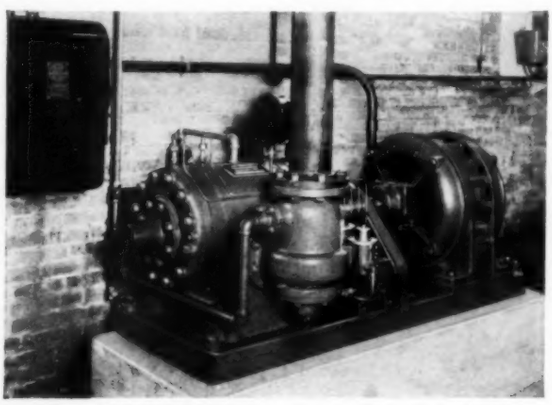
The new breakers are trip free from the operating handle and cannot be held in the closed position when an overload exists on the circuit. The "on" and "off" positions are clearly marked on the front cover and a yellow target appears in view when a breaker opens on an overload. No external arc is visible, only the click of the trip mechanism and the appearance of the target indicating that the breaker has tripped.

Overload tripping of the breakers is initiated through a bi-metallic thermal strip which, when heated by over-current, deflects and actuates the trip mechanism. This device has an inherent time lag inversely proportional to the magnitude of the overload. A short circuit will cause almost instantaneous trippings. The large breakers have both thermal time delay and instantaneous tripping, a spring toggle providing positive and speedy operation. All poles of multiple breakers operate simultaneously.

The breaker parts are enclosed in a housing of textolite and provision is made for mounting of the breaker in panelboards, dead-front distribution boards, or individual metal enclosures. All sizes are designed to fit the ordinary service entrance box.

## Rotary Air Compressors and Pumps

A complete line of new rotary air compressors and vacuum pumps of the multi-cellular, sliding-vane type, in both water-cooled and air-cooled designs, has been made available by Allis-Chalmers Manufacturing Co., Milwaukee, Wis. The line covers a range of volumes from 50 to 2,000 cfm at pressures up to 150 lb, and vacuums up to 29.85 in. of mercury. The air-cooled units are suitable for pressures up to 10 lb gage, and vacuums up to 18 in. Hg, and the water-cooled units for higher pressures and vacuums.



No belts or pulleys are normally required, as the units operate at standard motor speeds. The design is simple, involving no valves or complicated motions, and smooth operation, small dimensions, and continuous delivery are mentioned by the maker as features. Working parts are totally enclosed, easily accessible.

## Develops Laminated Packing

To meet the exacting service of high steam pressures, the Yarnall-Waring Co., Philadelphia, has developed a new form of laminaated packing for use in its seatless blow-off valves. This packing consists of several stainless-steel rings with long fiber asbestos packing between them. At the time of assembly the mass is compressed and heat treated, so that the finished ring is a complete unit suitable for high pressures and temperatures. A slight clearance is maintained between the metal laminations and the valve plunger.

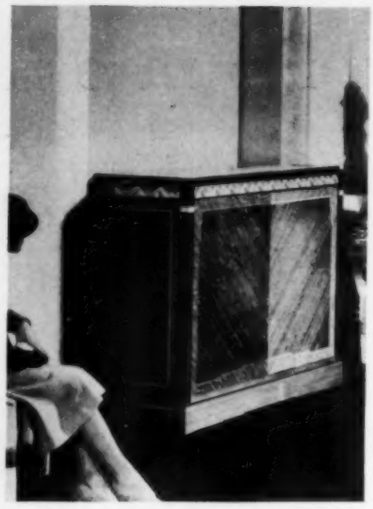
In the company's laboratory, the new packing rings have been subjected to blow-down tests at various steam pressures, ranging from 450 to 2100 lb. The tests were conducted with valve throttled, so that the operating conditions were more severe than those encountered in normal blow-down service. According to the manufacturer, the tests on the new packing showed that the construction practically eliminates blow-down leakage, even at pressures as high as 2,100 lb and under the throttling service mentioned. No evidence of wire drawing or breakdown of the ring was disclosed and long packing life was indicated.

## New Solenoid Globe Valve

A new electrically-operated solenoid globe valve which has a wide variety of applications in heating, piping and air conditioning work has been made available by The Wm. Powell Co., Cincinnati, Ohio. It is made with either a steam bronze or non-magnetic iron body on the side of which is a housing for the magnet or solenoid. When energized, the magnet pulls the ball from the valve seat horizontally (toward the rear in the illustration) and holds it against the metal division wall between the magnet and the valve body. When the current to the magnet is turned off, the ball rolls back on the seat, closing the valve. A steel ball is used for oil or non-corrosive service, while for severe conditions balls of stainless steel are recommended.

The ball—the only moving part—is totally enclosed and there is no packing. The valve will function on control lines buried underground or submerged in water, and may be used near explosive liquids or gases. On pilot burners it can be provided with a thermostat which automatically closes the valve should the pilot flame be extinguished.

## Mechanical Air Conditioner



The De La Vergne Engine Company, Philadelphia, Pa., has announced a new self-contained air-conditioning unit for use in offices, retail establishments, hotels, clubs, homes, etc., which operates entirely by electricity and is air cooled; it requires no water or refrigerant piping.

The unit employs the compression refrigeration cycle for cooling and dehumidifying, and a reverse-refrigeration principle for warming and humidifying. To change it from a cooling to a heating unit requires only the turning of a lever. Freon is the refrigerant.

The device is housed in a hardwood cabinet designed to harmonize with its surroundings; installation requires only an outlet sufficient to carry 2 kw of electrical energy, and air ducts arranged under a partially-raised window sash. Where window space is not available it is possible to install ducts to outside air in numerous ways, depending upon conditions. Moisture condensed from the air drains to a pan under the condenser where it is evaporated and conveyed outdoors in vapor form.

The 1½-ton compressor is a two-cylinder opposed vertical shaft unit direct-connected to a 2-hp vertical motor, totally enclosed in the machine. The two fans are direct-connected to ¼-hp motors.

With the use of the reverse refrigeration cycle for heating, it is stated that heat is extracted from the air by the heat pump, the number of heat units so extracted being equal to four or five times the number put into the unit in the form of electrical energy. For example, if one kw of electrical energy put into an ordinary resistance coil would produce 100 heat units, the same electrical energy put into the heat pump would produce from four hundred to five hundred heat units. The unit may be used in the heating season as an auxiliary source of heat, or solely as a ventilator by switching off the compressor.

## Simplifies "Smokeless" Principle

A simplified application of the cast-iron smokeless boiler principle for the combustion of bituminous coals has recently been made by Crane Co., Chicago. The device consists of two hollow risers and a hollow distributing arch, cast in a special chrome-iron, resistant to temperature and corrosion. The risers fit securely into the grate sockets, and lugs cast on the arch hold it in position. Four bolts insure tight and permanent installation. A special short grate is mounted on sockets cast on the risers.

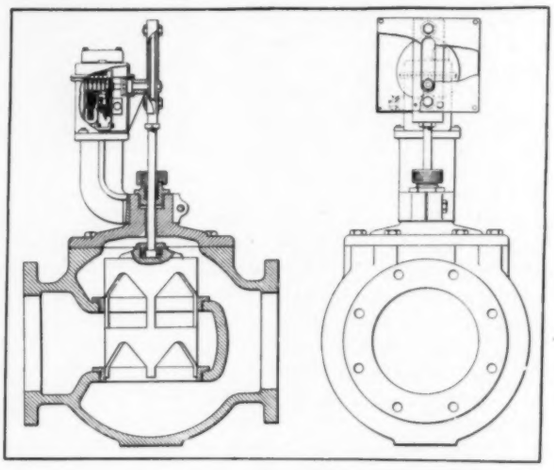
Secondary air conducted from the ashpit is preheated in passing through the risers to the distributing arch. As the hot air leaves the arch, it combines with the black volatile products distilled from soft coals, and the mixture burns at a high temperature over the red hot coals at the back of the firebox.

A feature of the attachment is that installation in a heating plant already in service does not necessitate removal of boiler sections or piping. Boilers ranging from outputs of 96,000 to 1,250,000 Btu may be supplied with this smokeless device.

## Large Motor-Operated Valves

Among the latest additions to the line of equipment comprising its electric system of temperature and humidity control are a number of motor-operated valves in the sizes larger than 2 in., according to a recent announcement by Barber-Colman Company, Rockford, Ill. By this means electrically-driven valves suitable for remote automatic or manual control can be supplied for many services which hitherto could not be taken care of.

There are three general types of these valves. The single seat



type with renewable composition disc is available in sizes from 2 to 6 in., will handle pressures from 80 to 90 lb., depending on the size, and is made with either positive or reversing motor-operators. The semi-balanced double bronze disc type is made with vee-port disc in 2 to 4-in. sizes and with standard disc in the 5, 6 and 8-in. sizes, either positive or reversing for 125-lb pressure. The largest one, the full-balanced vee-ported piston disc type is made in sizes from 5 to 12 in. with reversing operators only and for pressures up to 125 lb.

The diagram illustrates this last type.

## New Furnace Glaze

The Mildon Engineering Company, Inc., 25 Broadway, New York City, has developed a furnace glaze or vitrified coating for refractory walls. This coating, which does not contain silicate of soda, fuses progressively between 1200 and about 2800 F and does not re-fuse or run at much higher temperatures. (It has been tested above 3400 degrees). It becomes an integral part of the refractory and will not check or flake off, according to the maker. It is applicable to old linings as well as new.

## New Seamless Steel Boiler Tubes

Jones & Laughlin Steel Corporation, Pittsburgh, has announced a complete line of hot-rolled seamless steel boiler tubes. According to the manufacturer, these boiler tubes have exceptional ductility and lend themselves quite readily to rolling-in and beading operations. The surfaces both inside and outside

are made smooth to retard corrosion when the tubes are in use and to minimize depreciation while they are held in stock.

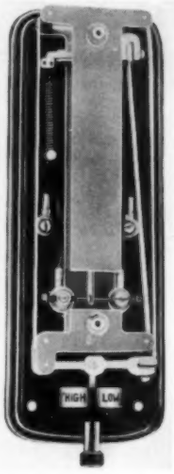
The product complies with the *A. S. M. E.* boiler code, *A. S. T. M.* specifications and the U. S. Steamboat Inspection Service rules and regulations. A push-bench mill, said to be the only one of its kind in this country, is used for manufacture.

## Check Valves with Flow Switch

A check valve equipped with a mercoid flow switch has been introduced by Barrett, Haentjens & Co., Hazleton, Pa. The purpose of the switch is to shut down the pump in the event that it loses its water during operation. The switch is connected into the low-voltage coil of the motor starter, and is actuated by the valve flap. When the pump is in operation and delivering water, the flow through the valve raises the flap and closes the switch. When the pump loses its water, the flap falls, the switch opens, and stops the pump.

The switch can be arranged for either horizontal or vertical mounting of the valve.

## Low-Voltage Humidity Control

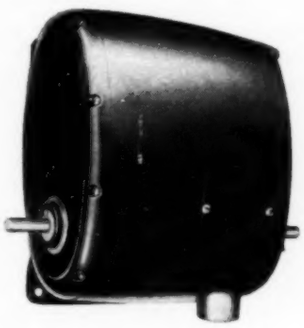



Lewis Air Conditioners, Inc., 829 Second Ave. S., Minneapolis, Minn., have developed a new open-contact low-voltage (up to 25 volts) humidity control for air conditioning use. Direct application can be made to equipment drawing less than 25 watts, and, like other low-voltage instruments, it can be used with equipment taking more than this by the use of a transformer-relay combination. The instrument can be set to control humidity at any point up to 100 per cent, according to the maker, and the "in" and "out' operating range can be adjusted to a 1-per cent differential. If no specifications are given, it is calibrated for 40 per cent with a 4-per cent differential.

The actuating element is of a ribbon type; the working mechanism is mounted on a base and fully insulated and protected. The cover and base are of dark walnut bakelite. Over-all dimensions: width, 2⅞ in.; length, 7⅞; depth, 1¼.

## Motors for Industrial Control

Minneapolis-Honeywell Regulator Company, 2701 Fourth Ave. S., Minneapolis, Minn., now offers a line of units for industrial control purposes. They consist of electric-motor-driven speed reducers, incorporating a motor element and reduction spur-gear trains. They are available for operation in accordance with the following modes of automatic control: Two-position, on and off, high-low; three-position; floating; proportioning. They are adaptable to damper regulation, and, in connection with motorized fuel-air valves, to regulate industrial furnace temperature and to adjust its atmosphere. Other uses include the direct drive of double seating valves of the sliding and rotary shaft stem classifications in a wide range of sizes serviceable in the district steam, industrial processing and power fields in connection with automatic controllers or remote station switches.



With the gear train and switching mechanism, the motors are assembled in a totally enclosed, dust- and splash-proof housing. Construction is compact and designed to withstand continuous duty. Detailed information is given in a bulletin recently issued.

## New Fan-Type Electric Heater

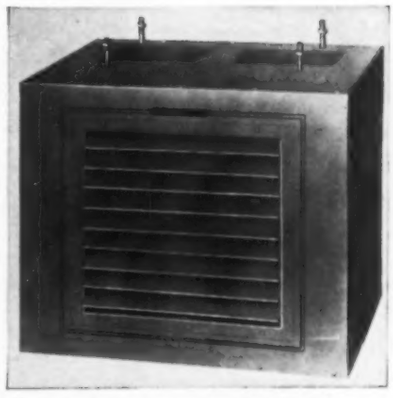
A new fan-type electric heater has been developed by Hynes Electric Heating Co., 240 Cherry St., Philadelphia, Pa.; the air flow is directed over electrically heated walls to control radiant heat and permit compact and substantial construction. The standard finish is black japan, but a bronze finish can be furnished when specified. The usual brackets are furnished for wall mounting of the units, but brackets for ceiling suspension are also available.

Capacities range from 1.5 to 12 kw, 180 to 1300 cfm, in various voltages and phases. Only a thermostat is required to control the 1.5-kw size, while larger sizes need a relay box as well.

## Floor and Ceiling-Type Conditioners

The new unit air conditioner made by Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa., cools and dehumidifies air in summer, heats and humidifies it in winter, and filters and circulates it at all times. These units are designed for installation under windows or along the wall; where space is limited, a special unit is available for wall or ceiling mounting which is especially applicable for lunch rooms and small shops.

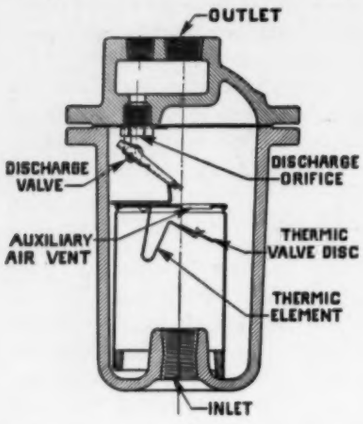
The units are especially adaptable for the restaurant, grill, barber shop, office, hotel, clothing shops, stores, etc. The floor models are available in four styles consisting of two finishes—a walnut finish and a modernistic cabinet finished in blue-green set off by a glossy micarta panel with colored metal inlays. Trim is of satin chrome.



In hot weather, cooling is accomplished by passing the air over cold coils in which a refrigerant (supplied by the refrigerating unit, located in the basement or in an adjacent room) is circulated. In cold weather, the air is heated by passing it over coils heated by the regular steam or hot-water heating system of the building.

Humidity is provided by circulating the incoming air through a fine water spray. The air is filtered to remove dust and foreign matter.

## Trap Has Automatic Air Bypass



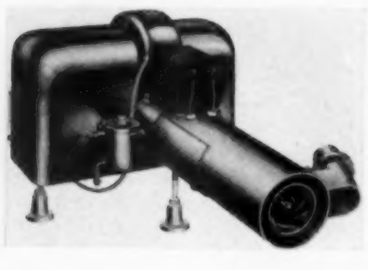

An automatic air bypass to promote quick heating and integral with its inverted bucket steam trap has been developed by the Armstrong Machine Works, Three Rivers, Mich. For quickly removing air from unit heaters, pipe-coil radiation, etc., a special trap bucket having a very large auxiliary air vent is offered. This vent is closed by a flat disc of stainless steel on the end of a strip of rustless thermostatic bi-metal which in turn is double riveted to the bucket cap. As long as the trap is cold, the disc is held away from the vent and air escapes so rapidly that the bucket cannot float and close the discharge valve. Air blows through until steam fills the radiation and reaches the trap, causing the thermic strip to seat the disc which prevents steam from escaping through the auxiliary vent. Thereafter, the trap functions in the normal manner, and any air that may be mixed with the steam will escape through the standard fixed vent.

## ½-Ton Spot Cooler

A spot cooler which is recommended for installation in small stores, restaurants, beauty parlors, barber shops, doctors' offices, waiting rooms, etc., has been placed on the market by Ilg Electric Ventilating Co., 2850 N. Crawford Ave., Chicago. It is a self-contained mechanical unit consisting of a double compressor, a double cooling coil and a self-cooled-motor propeller fan distributing air through a special deflector which provides for directing the air flow.

Capacity of the unit is 0.55 ton and the air delivery is 280 cfm. The motor size is ½ hp, 100-125 volt single phase a c or d-c current. Connections to the ordinary electric circuit and water line are required.

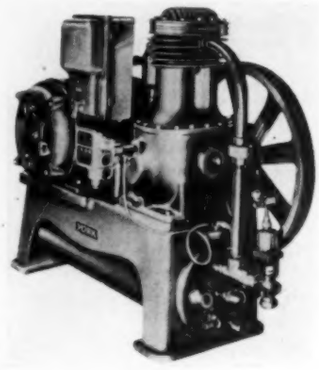
## Oil Burners Improved



An improved series of oil burners is described in detail in questionnaire form in a bulletin which has been issued by the Bethlehem Foundry & Machine Co., Bethlehem, Pa. One of the commercial models is shown here. Sizes in maximum rated capacities up to 7,000 sq ft of steam radiation are available.

These burners are of the pressure-atomizing, gun-type burning No. 3 fuel oil. Features include three-point suspension and special rubber cushions to prevent vibration. Ten mechanical improvements have been made in the series.

## New Compressors Use Freon



The York Ice Machinery Corporation, York, Pa., is now making new freon electric refrigerating compressors in thirty types and sizes for air conditioning and commercial applications (including beer dispensing units) and ranging in size from ¼ to 20 hp.

To reduce compressor friction and allow greater refrigerating capacity per kilowatt input, wearing surfaces on the compressor, such as cylinders, pistons and bearings are machined on special machines equipped with diamond tools, which are necessary to machine the nickel iron of which the surfaces are made.

The crankshaft sealing mechanism is packingless; valves are of Swedish steel.

For use with its refrigerating units, this company has recently issued two new bulletins, one on spiro-fin evaporators and the other on square-fin evaporators.

## Measures Temperature from Radiation

A radiated heat thermometer applying a new principle in temperature indication has been developed by Harvey B. Lindsay, President of the Dry-Zero Corporation, Merchandise Mart, Chicago, which should have a number of applications in the science of heating and air conditioning, in refrigeration and in several other fields. The principle can be applied to thermocouples, resistance bulbs, etc.

The method consists primarily of permitting the direct absorption of radiated energy by the expanding or otherwise actuated element of the measuring device, and at the same time so decreasing the loss of heat generated by such radiating impact by reflection, conduction, and re-radiation — particularly the latter—that the rate of heat acceptance of the element is so much greater than the rate of heat loss that the sensible heat therein builds up practically to the equivalent of the heat energy—both radiated and ambient—accepted.

By first taking a reading with the thermometer arranged so that the radiated energy falls directly on the measuring element, and then reversing the thermometer, being careful that it be shielded from re-radiation

(*To page 78, back Advertising Section*)

Heating·Piping
and Air Conditioning

# American Society of Heating and Ventilating Engineers JOURNAL SECTION

1895

JUNE 1933

## Table of Contents

The Heat Conductivity of Wood at Climatic Temperature Differences, by F. B. Rowley ..... 313

Indices of Air Change and Air Distribution, by F. C. Houghten and J. L. Blackshaw ..... 324

Welcome to Detroit! ..... 331

Local Chapter Reports ..... 334

Candidates for Membership ..... 336

Candidates Elected ..... 336

## OFFICERS AND COUNCIL 1933

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS
51 Madison Ave., New York, N. Y.

*President* ..... W. T. JONES

*First Vice-President* ..... C. V. HAYNES
*Second Vice-President* ..... JOHN HOWATT
*Treasurer* ..... D. S. BOYDEN
*Secretary* ..... A. V. HUTCHINSON

### COUNCIL

W. T. JONES, *Chairman* — C. V. HAYNES, *Vice-Chairman*

*One Year*

E. K. CAMPBELL, E. O. EASTWOOD, ROSWELL FARNHAM, E. HOLT GURNEY, F. B. ROWLEY

*Two Years*

F. E. GIESECKE, G. L. LARSON, W. E. STARK, J. F. McINTIRE

*Three Years*

R. H. CARPENTER, J. D. CASSELL, L. WALTER MOON, F. C. McINTOSH

### COMMITTEES OF THE COUNCIL

*Executive:* C. V. HAYNES, *Chairman*
G. L. LARSON, F. B. ROWLEY

*Finance:* JOHN HOWATT, *Chairman*
R. H. CARPENTER, F. C. McINTOSH

*Meetings:* ROSWELL FARNHAM, *Chairman*
E. O. EASTWOOD, J. F. McINTIRE

*Membership:* E. K. CAMPBELL, *Chairman*
E. HOLT GURNEY, L. WALTER MOON

### ADVISORY COUNCIL

F. B. Rowley, *Chairman;* W. H. Carrier, Homer Addams, F. Paul Anderson, R. P. Bolton, S. E. Dibble, W. H. Driscoll, H. P. Gant, John F. Hale, L. A. Harding, H. M. Hart, E. Vernon Hill, J. D. Hoffman, S. A. Jellett, D. D. Kimball, S. R. Lewis, Thornton Lewis, J. I. Lyle, J. R. McColl, D. M. Quay, C. L. Riley, F. R. Still and A. C. Willard.

### COOPERATING COMMITTEES

A. S. H. V. E. representative on *National Research Council;* Prof. A. C. Willard (3 years).

### SPECIAL COMMITTEES

*Committee on Admission and Advancement:* J. D. Cassell, *Chairman (one year);* F. D. Mensing *(two years),* and A. J. Offner *(three years).*

*Publication Committee:* W. E. Stark, *Chairman (one year);* W. M. Sawdon *(two years),* and A. P. Kratz *(three years).*

*Committee on Constitution and By-Laws:* Thornton Lewis, *Chairman;* R. H. Carpenter and W. E. Stark.

*Committee on Chapter Relations:* E. K. Campbell, *Chairman.*

*Guide Publication Committee:* W. L. Fleisher, *Chairman;* D. S. Boyden, F. E. Giesecke, S. R. Lewis and Perry West.

*Committee on Code for Testing and Rating Convectors:* R. N. Trane, *Chairman;* E. H. Beling, R. F. Connell, J. H. Holton, Hugo Hutzel, A. P. Kratz, M. G. Steele and O. G. Wendel.

*Committee on Nomenclature:* S. R. Lewis, *Chairman;* W. H. Carrier, P. D. Close, W. H. Driscoll, L. A. Harding, Thornton Lewis, J. F. McIntire and A. C. Willard.

*Committee on Ventilation Standards:* W. H. Driscoll, *Chairman;* J. J. Aeberly, F. Paul Anderson, L. A. Harding, D. D. Kimball, J. R. McColl, C. L. Riley, W. A. Rowe, Perry West and A. C. Willard.

### NOMINATING COMMITTEE FOR 1933

| *Chapters* | *Representative* | *Alternate* |
|---|---|---|
| Cincinnati | H. E. Sproull | A. A. Blomfeldt |
| Cleveland | C. F. Eveleth | F. A. Kitchen |
| Illinois | J. J. Aeberly | J. J. Hayes |
| Massachusetts | E. Q. Cole | W. W. Murphy |
| Michigan | J. H. Walker | H. E. Paetz |
| Western Michigan | S. H. Downs | J. H. Van Alsburg |
| Minnesota | C. E. Lewis | A. J. Huch |
| New York | Russell Donnelly | Walter Heibel |
| Western New York | M. C. Beman | D. J. Mahoney |
| Pacific Northwest | E. L. Weber | P. M. O'Connell |
| Philadelphia | W. R. Eichberg | M. F. Blankin |
| Pittsburgh | R. B. Stanger | F. C. McIntosh |
| St. Louis | C. A. Pickett | C. R. Davis |
| Wisconsin | E. A. Jones | Ernest Szekely |

# COMMITTEE ON RESEARCH

G. L. LARSON, *Chairman*

J. H. WALKER, *Vice-Chairman* — PROF. A. C. WILLARD, *Technical Adviser* — F. C. HOUGHTEN, *Director*

O. P. HOOD, *Ex-Officio Member*

*One Year*

C. A. BOOTH, F. B. HOWELL, WALTER KLIE, E. N. SANBERN, J. H. WALKER

*Two Years*

D. E. FRENCH, F. E. GIESECKE, L. A. HARDING, G. L. LARSON, A. P. KRATZ

*Three Years*

ALBERT BUENGER, S. H. DOWNS, H. N. KITCHELL, H. R. LINN, PERRY WEST

## Executive Committee

G. L. LARSON, *Chairman*

C. A. BOOTH, L. A. HARDING

## Finance Committee

J. H. WALKER, *Chairman*

E. C. EVANS, C. V. HAYNES, THORNTON LEWIS, R. N. TRANE

## TECHNICAL ADVISORY COMMITTEES - 1933-1934

*Air Conditions and Their Relation to Living Comfort:* C. P. Yaglou, *Chairman;* J. J. Aeberly, W. L. Fleisher, D. E. French, Dr. R. R. Sayers and Dr. C.-E. A. Winslow.

*Air Flow through Registers and Grilles:* John Howatt, *Chairman;* J. J. Aeberly, L. E. Davies, D. E. French and J. J. Haines.

*Atmospheric Dust and Air Cleaning Devices (Including Dust and Smoke):* H. C. Murphy, *Chairman;* J. J. Bloomfield, Albert Buenger, Philip Drinker, Dr. E. V. Hill, S. R. Lewis, H. B. Meller, Games Slayter and Dr. S. W. Wynne.

*Correlating Thermal Research:* R. M. Conner, *Chairman;* D. S. Boyden, J. C. Fitts, H. T. Richardson and Perry West.

*Corrosion:* J. H. Walker, *Chairman;* H. F. Bain, E. L. Chappell, W. H. Driscoll and R. R. Seeber.

*Direct and Indirect Radiation with Gravity Air Circulation:* H. F. Hutzel, *Chairman;* A. P. Kratz, H. R. Linn, J. F. McIntire, J. P. Magos, T. A. Novotney, R. N. Trane and G. L. Tuve.

*Gas Heating Equipment:* W. E. Stark, *Chairman;* Robert Harper, E. A. Jones, Thomson King, J. F. McIntire and H. L. Whitelaw.

*Heat Transfer of Finned Tubes with Forced Air Circulation:* F. B. Rowley, *Chairman;* H. F. Bain, H. F. Hutzel, W. G. King, A. P. Kratz, E. J. Lindseth, G. L. Tuve and W. E. Stark.

*Heat Transmission (Heat Received by and Emitted by Buildings in Relation to Living Comfort):* P. D. Close, *Chairman;* A. B. Algren, R. E. Backstrom, A. E. Stacey, Jr. and J. H. Walker.

*Infiltration in Buildings:* D. W. Nelson, *Chairman;* V. W. Hunter, W. C. Randall, E. N. Sanbern, J. G. Shodron and Ernest Szekely.

*Oil Burning Devices:* H. F. Tapp, *Chairman;* Elliott Harrington, F. B. Howell, J. H. McIlvaine and L. E. Seeley.

*Pipe and Tubing (Sizes) Carrying Low Pressure Steam or Hot Water:* S. R. Lewis, *Chairman;* J. C. Fitts, F. E. Giesecke, H. M. Hart, C. A. Hill, R. R. Seeber and W. K. Simpson.

*Refrigeration in Relation to Air Treatment:* A. P. Kratz, *Chairman;* E. A. Brandt, E. D. Milener, K. W. Miller, F. G. Sedgwick, J. H. Walker and R. W. Waterfill.

*Sound in Relation to Heating and Ventilation:* Warren Ewald, *Chairman;* C. A. Andree, Carl Ashley, C. A. Booth, V. O. Knudsen, R. F. Norris, J. P. Reis and G. T. Stanton.

*Ventilation of Garages and Bus Terminals:* E. K. Campbell, *Chairman;* S. H. Downs, T. M. Dugan, E. C. Evans, F. H. Hecht, H. L. Moore and A. H. Sluss.

# OFFICERS OF LOCAL CHAPTERS 1933-1934

### CLEVELAND
Headquarters, Cleveland
*Meets: Second Friday in Month*
*President,* R. G. DAVIS
400—The Ninth—Vincent Bldg.
*Secretary,* F. A. KITCHEN
1514 Prospect Ave.

### CINCINNATI
Headquarters, Cincinnati, O.
*Meets: Second Tuesday in Month*
*President,* K. A. WRIGHT
1113 Race St.
*Secretary,* G. B. HOULISTON
704 Race St.

### ILLINOIS
Headquarters, Chicago
*Meets: Second Monday in Month*
*President,* J. H. O'BRIEN
228 N. LaSalle St.
*Secretary,* J. J. HAYES
53 W. Jackson Blvd.

### KANSAS CITY
Headquarters, Kansas City, Mo.
*Meets: Second Monday in Month*
*President,* DAVID CALEB
1330 Baltimore Ave.
*Secretary,* C. A. WEISS
1811 Troost Ave.

### MASSACHUSETTS
Headquarters, Boston
*Meets: First Monday in Month*
*President,* LESLIE CLOUGH
Box 34, Weymouth, Mass.
*Secretary,* E. W. BERCHTOLD
100 Arlington St.

### MICHIGAN
Headquarters, Detroit
*Meets: First Monday after the 10th of the Month*
*President,* H. E. PAETZ
2539 Woodward Ave.
*Secretary,* TOM BROWN
487 W. Alexandrine Ave.

### WESTERN MICHIGAN
Headquarters, Grand Rapids
*Meets: Second Monday in Month*
*President,* D. L. TAZE,
604 Building and Loan Bldg.
*Secretary,* P. O. WIERENGA,
49 Coldbrook St., N. E.

### MINNESOTA
Headquarters, Minneapolis
*Meets: Second Monday in Month*
*President,* W. F. UHL
132 S. 10th St.
*Secretary,* C. E. LEWIS
829 2nd Ave.

### NEW YORK
Headquarters, New York
*Meets: Third Monday in Month*
*President,* H. L. ALT
65 Fourth Ave., Newark, N. J.
*Secretary,* T. W. REYNOLDS
109 West 96th St.

### NEW YORK UNIVERSITY STUDENT CHAPTER
Headquarters, New York University
*President,* HERBERT MAIMAN
78-65 80th St., Glendale, L. I., N. Y.
*Secretary,* ABRAHAM RAFFES
977 East 178th St., New York, N. Y.

### WESTERN NEW YORK
Headquarters, Buffalo
*Meets: Second Monday in Month*
*President,* D. J. MAHONEY
503 Franklin St.
*Secretary,* W. E. VOISINET
250 Delaware Ave.

### ONTARIO
Headquarters, Toronto, Can.
*Meets: First Monday Every Other Month*
*President,* W. P. BODDINGTON
106 Lombard St.
*Secretary,* H. R. ROTH
1104 Bay St.

### PACIFIC NORTHWEST
Headquarters, Seattle, Wash.
*Meets: Second Thursday in Month*
*President,* C. F. TWIST
967 Thomas St.
*Secretary,* S. D. PETERSON
5051 Prince St.

### PHILADELPHIA
Headquarters, Philadelphia
*Meets: Second Thursday in Month*
*President,* M. F. BLANKIN
1518 Fairmount Ave.
*Secretary,* W. R. EICHBERG
4210 Sansom St.

### PITTSBURGH
Headquarters, Pittsburgh
*Meets: First Monday in Month*
*President,* G. S. MCELLROY
R. D. 2, Glenshaw, Pa.
*Secretary,* J. L. BLACKSHAW
3728 Dawson St.

### ST. LOUIS
Headquarters, St. Louis
*Meets: First Wednesday in Month*
*President,* C. A. PICKETT
2628 Olive St.
*Secretary,* C. R. DAVIS
2328 Locust St.

### SOUTHERN CALIFORNIA
Headquarters, Los Angeles
*Meets: First Tuesday after the 10th of the Month*
*President,* L. H. POLDERMAN
748 E. Washington St.
*Secretary,* E. H. KENDALL
1224 S. San Pedro St.

### WISCONSIN
Headquarters, Milwaukee
*Meets: Third Monday in Month*
*President,* V. A. BERGHOEFER
4080 N. 24th St.
*Secretary,* C. H. RANDOLPH
918 N. Van Buren St.

# The Heat Conductivity of Wood at Climatic Temperature Differences*

By F. B. Rowley,† *Member*,
Minneapolis, Minn.

*A co-operative research project between the* AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, *The National Lumber Manufacturers' Association, and the University of Minnesota.*

THE thermal properties of wood are of importance both in building construction to conserve fuel and improve living conditions, and in the field of refrigeration. Little information on the subject has previously been available, and the few tests on which previous fragmentary data have been based have omitted to record sufficient data on the character and condition of material tested so that results could be interpreted in terms of general utility or extended to apply to species not tested.

In 1929, therefore, a preliminary study was made to determine the feasibility of a more extended research program and to identify the factors which might require investigation.

Based on the results of this preliminary program, the project was extended to cover about thirty species of wood and to determine the effect of density and moisture content on the thermal conductivity of several representative species. The work has been a cooperative project between the University of Minnesota, the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, and the *National Lumber Manufacturers' Association.*

The thermal properties of wood as used in practice are influenced by a number of factors, of which the more important are species, density, moisture content, direction of heat flow, inclination of grain, and relation of volume or thickness to moisture content.

## Preliminary Investigation

The work in 1929 included over 100 tests of selected panels from 14 species, the material being selected by the U. S. Forest Products Laboratory as representative in character. Study of the results led to the following tentative conclusions:

1. That conductivity varies approximately in a straight line ratio with density in any given species.
2. That somewhat greater conductivity may be expected tangential to grain (*i. e.*, in edge-grain material) than radially, in species with strongly marked annual rings.
3. That no consideration need be given to the position of annual rings in species of uniform grain.
4. That small crevices such as occur between boards in ordinary construction do not materially affect conductivity over the area tested, though they may, in the absence of suitable precautions, affect air infiltration.
5. That conductivity varies substantially in a straight line ratio with moisture content if the latter is expressed in terms of weight per volume of wood.
6. That the inherent variability of wood makes a considerable number of tests of each species necessary in order to arrive at a fairly representative value for each species.

## Full Scale Investigation

Pursuant to the above findings, the following commercial species were selected for investigation:

| | |
|---|---|
| California Redwood | Soft Elm |
| Douglas Fir | Soft Maple |
| Eastern Hemlock | Sugar Pine |
| Hard Maple | Western Red Cedar |
| Longleaf Yellow Pine | West Coast Hemlock |
| Norway Pine | Western Larch |
| Ponderosa Pine | White Ash |
| Red Cypress | White Fir |
| Red Oak | White Oak |
| Shortleaf Yellow Pine | Northern White Pine |
| Sitka Spruce | Yellow Birch |

Samples of each of these species were selected covering the range of density normally experienced in that species, and tested to determine the relation between thermal conductivity and density and the average conductivity for the species. In order to reduce the volume of test work for a complete determination of the moisture-conductivity relation, they were divided into six groups and a single species from each group was tested. The groups and representatives selected for test were as follows:

| SPECIES IN GROUP | REPRESENTATIVE SPECIES TESTED |
|---|---|
| Norway Pine<br>Sugar Pine<br>Northern White Pine<br>Ponderosa Pine | Ponderosa Pine |
| California Redwood<br>Western Red Cedar<br>Red Cypress | Red Cypress |
| Douglas Fir<br>Longleaf Yellow Pine<br>Western Larch<br>Shortleaf Yellow Pine | Shortleaf Yellow Pine |
| Eastern Hemlock<br>Sitka Spruce<br>White Fir<br>West Coast Hemlock | West Coast Hemlock |
| White Ash<br>White Oak<br>Red Oak | White Oak and Red Oak |

*For presentation at the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, June, 1933, Detroit, Mich.

†Director, Experimental Engineering Laboratories, University of Minnesota.

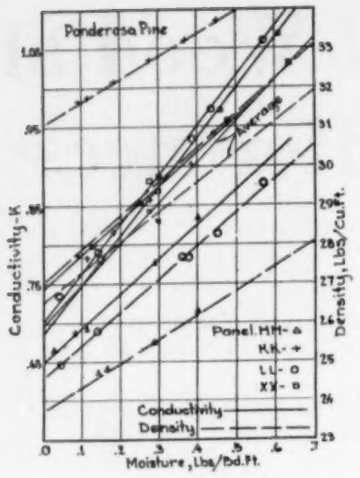



Fig. 1—Ponderosa Pine —The effect of moisture on density and conductivity

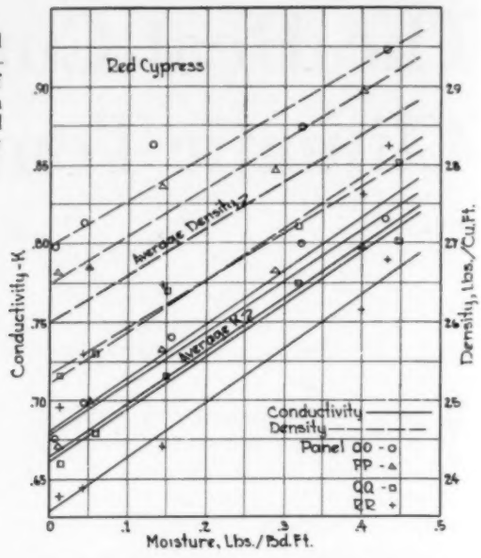



Fig. 2—Red Cypress—The effect of moisture on density and conductivity

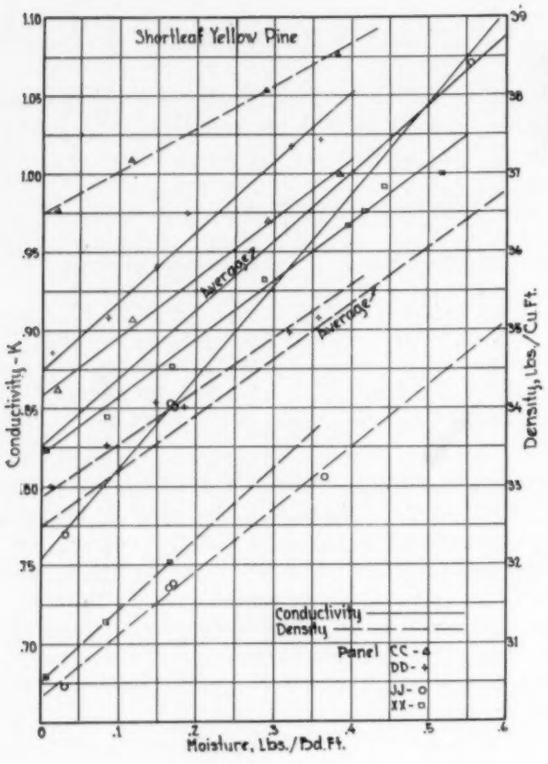



Fig. 3—Shortleaf Yellow Pine—The effect of moisture on density and conductivity

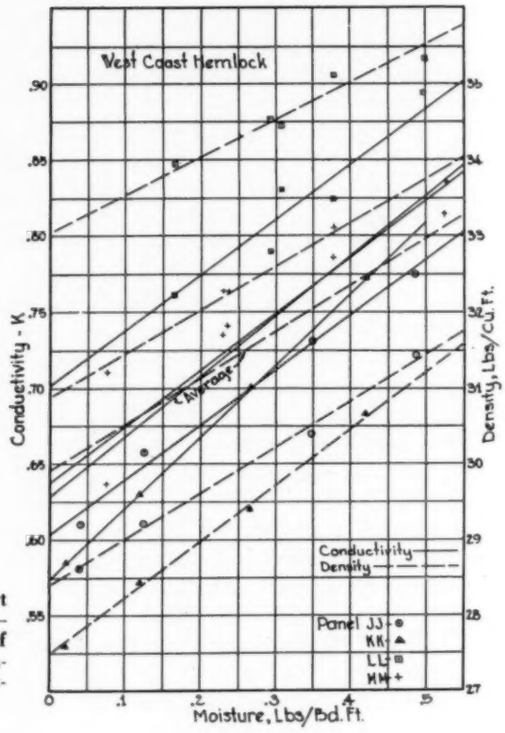



Fig. 4—West Coast Hemlock—The effect of moisture on density and conductivity

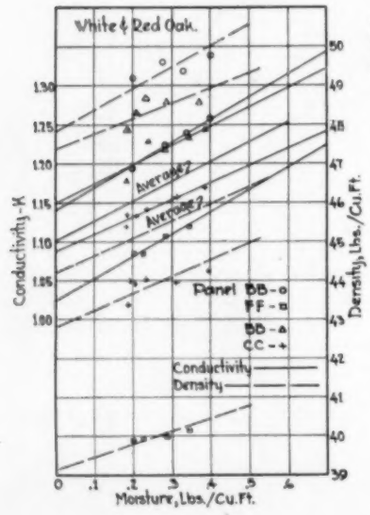



Fig. 5—White and Red Oak—The effect of moisture on density and conductivity

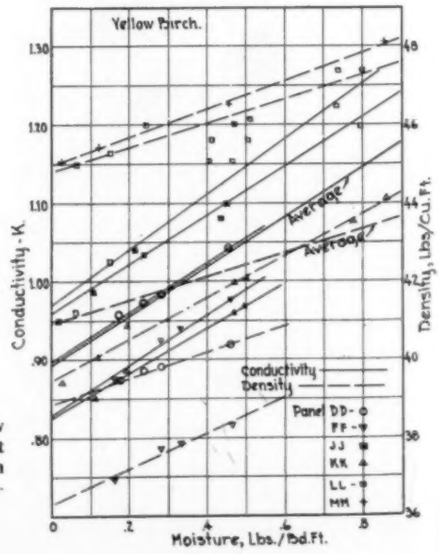



Fig. 6—Yellow Birch—The effect of moisture on density and conductivity

Hard Maple
Soft Elm
Soft Maple — Yellow Birch
Yellow Birch

For the six species selected as representatives of the various groups, a number of tests were made at various moisture contents to determine the moisture-thermal conductivity relation. The curve obtained from each of these samples was taken as a typical moisture-conductivity relation for each of the other species in the group. While this procedure leaves some doubt as to whether the results for the species tested apply accurately for the others in the group represented, the similarity of cell structure and other pertinent characteristics makes it probable that any departures involved are less than might be experienced in any one sample of the species actually tested.

### Selection of Samples

The samples were selected by the *National Lumber Manufacturers Association* and conditioned to approximately 8 per cent of moisture. These samples were sent to the University of Minnesota where they were selected in order to get uniform test panels of different densities. In this selection, boards of substantially the same densities were used to make up a pair of test panels, and panels were made up covering as wide a range of densities as possible from each species.

When the tests were first started, test samples 24 in. square were prepared for testing in the 24-in. hot plate. It later developed that the results obtained from the 12-in. hot plate were equally dependable and that it was possible to select much more uniform samples of this size. The majority of the tests, therefore, were run on 12-in. square panels. Those samples, a part of which were tested by the 24-in. hot plate, were: Douglas Fir, Western Red Cedar, White Fir, and Red Cypress. These samples are indicated in Table 2 by asterisks.

### Preparation of Samples

In preparing the test panels, the boards for a complete set were run through a planer in order to give a smooth surface on both sides and to make sure that all of the boards for each sample were of uniform thickness. The boards were then weighed and selected for density. A sample was taken from each board for moisture determination; the average of the results for all boards of a pair of test panels was taken as the average for the test.

The pieces used for moisture determination were wrapped in oiled paper as soon as cut from the test specimen. They were then taken to the Laboratory, weighed, and dried to a constant weight at 175 F. The loss of weight divided by the dry weight was taken as the percentage of moisture in the sample.

In some of the earlier tests, the moisture determinations were made at 212 F. These species were: Douglas Fir, White Fir, and Western Cedar. All others were dried at 175 F. In the case of Red Oak, the moisture content samples were dried at both 175 F and 212 F, which resulted in an increase of about 1 per cent in loss for the higher temperature.

For some of the samples, there was a slight variation in the moisture content during the test, which was determined by weighing the panels both before and after testing. In these cases, the average moisture content was taken as the moisture content for the particular test, although the variation was so slight in most cases that it was not necessary to take averages. An investigation was made to determine the effect of this moisture change during the test on thermal conductivity as obtained by the hot plate. It was shown that even though all of the heat for evaporating the moisture might come from that supplied to the test section the error would be less than one per cent and in all cases negligible.

When the moisture content of a panel is given as the percentage by weight, the test results may be misleading, due to the fact that for the same percentage by weight there will be different amounts of moisture per unit volume. For this reason, the percentage of moisture by weight was converted to pounds of moisture per board foot. In making this conversion, the volume of the sample was determined by measuring the length and width and by taking the thickness as determined in the test plate. The formula used for making the conversion was as follows:

$$\text{Weight of moisture per bd ft (144 cu in.)} = \frac{\text{(Average moisture \% before and after test, dry basis)} \times \text{(dry wt sample)} \times 144}{\text{(2} \times \text{thickness of 1 panel)} \times \text{length} \times \text{width}}$$

### Density

Since, in some cases, there might be a slight change in weight during the test, the density calculations were all made on the basis of weight and thickness taken at the beginning of the test, the change in density for a slight change in moisture being negligible. The warping of wood which sometimes occurs during a test might give a greater thickness reading of the test panel at the end of the test than at the beginning, even though no additional moisture was added. In some cases, there was a slight warping of the test boards before the test, making it necessary to take the thickness readings of the individual boards and not to use the thickness as obtained during the test. When there was any appreciable warping, additional samples were selected and tested. In all cases of tests upon which the present data have been based, the density has been determined by the following formula:

$$\text{Density, lb per cu ft before test} = \frac{1728 \times \text{weight before test}}{\text{(2} \times \text{thickness of 1 panel)} \times \text{length} \times \text{width (before test)}}$$

### Method of Tests

All thermal conductivity tests were made with standard hot plate apparatus, and in practically all of the tests, the 12-in. square plates were used. In each case, the test samples were prepared and the panels were placed in the test plate and left at constant conditions a sufficient length of time to insure uniform temperature gradients throughout the specimen. The temperatures of the test surfaces were then taken and the rate of heat flow through the test section was calculated from the electric input to the heating element. Readings at constant conditions were continued for average periods of five hours in order to insure uniform data. The thickness of the sample from which the thermal conductivities were calculated was taken as the distance between the test plates during the test.

## Table 1—Test Data for Moisture-Density and Moisture-Conductivity Correction Curves

| Species | Panels | Test No. | Composed of Boards | Moisture Per Cent by Weight Dry Basis | Moisture Lb/Bd Ft as Tested | Density Lb/Cu Ft as Tested | Conductivity "K" 75° M. T. |
|---|---|---|---|---|---|---|---|
| Ponderosa Pine | HH′ | 881 | H3, H4, H5 I3 | 1.85 | 0.036 | 23.86 | 0.665 |
| | | 877 | | 3.47 | 0.067 | 24.10 | 0.679 |
| | | 873 | | 7.54 | 0.144 | 24.70 | 0.713 |
| | | 545 | | 8.73 | 0.166 | 24.83 | 0.718 |
| | | 891 | | 15.83 | 0.289 | 25.47 | 0.774 |
| | | 899 | | 22.65 | 0.401 | 26.29 | 0.836 |
| | KK′ | 865 | K1, K2 K3, K4, K5 | 3.62 | 0.092 | 31.64 | 0.792 |
| | | 882 | | 4.41 | 0.112 | 31.72 | 0.794 |
| | | 864 | | 7.24 | 0.181 | 32.14 | 0.815 |
| | | 889 | | 11.30 | 0.276 | 32.67 | 0.861 |
| | | 902 | | 15.48 | 0.370 | 33.19 | 0.901 |
| | | 900 | | 18.85 | 0.444 | 33.71 | 0.945 |
| | LL′ | 733 | L1, L2, L3, L4 | 1.99 | 0.041 | 24.90 | 0.728 |
| | | 729 | | 6.68 | 0.135 | 25.77 | 0.787 |
| | | 756 | | 7.01 | 0.141 | 25.74 | 0.782 |
| | | 723 | | 18.40 | 0.355 | 27.65 | ..... |
| | | 770 | | 19.37 | 0.372 | 27.63 | 0.927 |
| | | 762 | | 23.65 | 0.448 | 28.23 | 0.984 |
| | | 759 | | 29.69 | 0.563 | 29.54 | 1.058 |
| | XX′ | 440 | J1, J3, K1, K2, K3, K4, L1, L2, L3, L4 | 5.78 | 0.133 | ..... | 0.803 |
| | | 781 | | 12.55 | 0.275 | 29.61 | 0.865 |
| | | 752 | | 13.67 | 0.294 | 29.34 | 0.861 |
| | | 746 | | 13.94 | 0.301 | 29.74 | 0.853 |
| | | 767 | | 22.54 | 0.476 | 31.14 | 0.986 |
| | | 764 | | 29.88 | 0.631 | 32.61 | 1.083 |
| Red Cypress | OO′ | 656 | L1, M3, M4, K1 | 0.29 | 0.007 | 26.95 | 0.675 |
| | | 642 | | 1.95 | 0.044 | 27.26 | 0.698 |
| | | 620 | | 7.08 | 0.156 | 28.25 | 0.740 |
| | | 711 | | 15.75 | 0.322 | 28.47 | 0.800 |
| | | 689 | | 21.33 | 0.430 | 29.44 | 0.816 |
| | PP′ | 657 | K2, L2, M1, M2 | 0.51 | 0.012 | 26.62 | 0.671 |
| | | 641 | | 2.36 | 0.052 | 26.70 | 0.700 |
| | | 621 | | 6.67 | 0.144 | 27.74 | 0.733 |
| | | 710 | | 14.22 | 0.289 | 27.92 | 0.783 |
| | | 688 | | 20.02 | 0.401 | 28.94 | 0.798 |
| | QQ′ | 658 | K3, K4, L3, J5 | 0.71 | 0.015 | 25.31 | 0.660 |
| | | 640 | | 2.78 | 0.058 | 25.62 | 0.679 |
| | | 623 | | 7.29 | 0.150 | 26.40 | 0.716 |
| | | 713 | | 16.38 | 0.318 | 27.20 | 0.775 |
| | | 687 | | 22.16 | 0.446 | 28.04 | 0.802 |
| | RR′ | 655 | L4, J2, J4, L5 | 0.60 | 0.013 | 24.90 | 0.639 |
| | | 643 | | 2.04 | 0.043 | 25.58 | 0.645 |
| | | 619 | | 7.08 | 0.145 | 26.47 | 0.671 |
| | | 712 | | 20.82 | 0.401 | 27.62 | 0.758 |
| | | 690 | | 22.81 | 0.433 | 28.23 | 0.789 |
| Shortleaf Yellow Pine | CC′ | 883 | B2, C2 | 0.06 | 0.020 | 36.52 | 0.862 |
| | | 879 | | 3.89 | 0.116 | 37.17 | 0.907 |
| | | 893 | | 10.05 | 0.289 | 38.06 | 0.969 |
| | | 905 | | 13.54 | 0.382 | 38.53 | 0.998 |
| | DD′ | 884 | D3, D1 | 0.47 | 0.013 | 33.01 | 0.886 |
| | | 880 | | 3.13 | 0.085 | 33.52 | 0.908 |
| | | 876 | | 5.45 | 0.147 | 34.08 | 0.940 |
| | | 434 | | 6.95 | 0.185 | 34.01 | 0.974 |
| | | 906 | | 12.34 | 0.319 | 34.95 | 1.017 |
| | | 908 | | 13.91 | 0.357 | 35.14 | 1.021 |
| | JJ′ | 732 | J2, J3, K3, L3 | 1.23 | 0.031 | 30.45 | 0.770 |
| | | 728 | | 6.65 | 0.165 | 31.70 | 0.853 |
| | | 757 | | 6.85 | 0.170 | 31.76 | 0.851 |
| | | 722 | | 15.31 | 0.366 | 33.10 | ..... |
| | | 770 | | 24.11 | 0.552 | ..... | 1.070 |
| | | 759 | | 29.31 | 0.671 | 35.66 | 1.153 |
| | XX′ | 453 | J1, J3, K1, K2, L2, L3 | 0.21 | 0.006 | 30.58 | 0.824 |
| | | 438 | | 3.33 | 0.084 | 31.28 | 0.845 |
| | | 429 | | 6.75 | 0.167 | 32.03 | 0.877 |
| | | 782 | | 11.99 | 0.284 | 31.79 | 0.932 |
| | | 753 | | 16.90 | 0.392 | 32.60 | 0.966 |
| | | 747 | | 17.78 | 0.413 | 32.95 | 0.976 |
| | | 768 | | 19.15 | 0.438 | 32.78 | 0.992 |
| | | 764 | | 22.87 | 0.514 | 33.25 | 0.999 |
| West Coast Hemlock | JJ′ | 668 | J2, K5 L4, L2 | 1.72 | 0.041 | 28.60 | 0.610 |
| | | 666 | | 5.38 | 0.125 | 29.20 | 0.657 |
| | | 726 | | 16.14 | 0.348 | 30.40 | 0.730 |
| | | 714 | | 23.15 | 0.484 | 31.43 | 0.774 |
| | KK′ | 670 | K5, K4, J3, K3 | 0.93 | 0.021 | 27.60 | 0.585 |
| | | 664 | | 5.30 | 0.119 | 28.44 | 0.630 |
| | | 787 | | 12.13 | 0.265 | 29.40 | 0.700 |
| | | 871 | | 19.79 | 0.419 | 30.67 | 0.772 |
| | LL′ | 663 | L2, M1, L3, M2 | 6.18 | 0.165 | 33.95 | 0.761 |
| | | 789 | | 11.28 | 0.292 | 34.52 | 0.790 |
| | | 788 | | 11.93 | 0.307 | 34.44 | 0.830 |
| | | 725 | | 14.76 | 0.375 | 35.10 | 0.824 |
| | | 717 | | 20.36 | 0.496 | 35.30 | 0.893 |
| | MM′ | 667 | L4, M5, M3, M4 | 2.98 | 0.076 | 31.20 | 0.637 |
| | | 790 | | 9.35 | 0.230 | 32.27 | 0.735 |
| | | 786 | | 9.55 | 0.235 | 32.25 | 0.741 |
| | | 727 | | 15.78 | 0.375 | 33.10 | 0.786 |
| | | 715 | | 21.84 | 0.523 | 33.70 | 0.813 |
| White Oak | BB′ | 761 | D2, D3, D3, D1 | 5.13 | 0.200 | 49.18 | 1.197 |
| | | 483 | | 7.18 | 0.276 | 49.54 | 1.221 |
| | | 878 | | 8.67 | 0.328 | 49.32 | 1.235 |
| | | 892 | | 10.61 | 0.398 | 49.75 | 1.255 |
| | FF′ | 591 | I1, I1, I2, I2 | 6.46 | 0.201 | 39.85 | 1.084 |
| | | 486 | | 7.38 | 0.223 | 39.96 | 1.086 |
| | | 888 | | 9.35 | 0.285 | 39.94 | 1.108 |
| | | 896 | | 11.43 | 0.343 | 40.16 | 1.122 |
| Red Oak | BB′ | 939 | B2, B2, B3, B3 | 4.83 | 0.184 | 47.85 | 1.180 |
| | | 576 | | 5.54 | 0.211 | 48.26 | 1.202 |
| | | 492 | | 6.07 | 0.232 | 48.64 | 1.226 |
| | | 913 | | 7.69 | 0.289 | 48.57 | 1.221 |
| | | 909 | | 8.76 | 0.326 | 48.47 | 1.231 |
| | | 925 | | 10.09 | 0.370 | 48.54 | 1.241 |
| | CC′ | 940 | D3, D2, D3, G1 | 5.46 | 0.187 | 43.35 | 1.120 |
| | | 903 | | 5.54 | 0.193 | 43.95 | 1.137 |
| | | 577 | | 5.98 | 0.206 | 43.90 | 1.133 |
| | | 495 | | 6.75 | 0.232 | 44.01 | 1.140 |
| | | 911 | | 9.13 | 0.307 | 43.91 | 1.156 |
| | | 921 | | 11.93 | 0.393 | 44.23 | 1.172 |
| Yellow Birch | DD′ | 861 | G1, G2, G3, H1 | 5.69 | 0.177 | 39.46 | 0.958 |
| | | 857 | | 7.75 | 0.238 | 39.71 | 0.973 |
| | | 516 | | 9.28 | 0.282 | 39.81 | 0.985 |
| | | 901 | | 15.73 | 0.456 | 40.40 | 1.043 |
| | FF′ | 862 | K1, D1, D2, D4 | 5.60 | 0.163 | 36.90 | 0.876 |
| | | 890 | | 9.84 | 0.282 | 37.73 | 0.926 |
| | | 886 | | 11.78 | 0.332 | 37.88 | 0.940 |
| | | 898 | | 16.90 | 0.461 | 38.38 | 0.977 |
| | JJ′ | 662 | J1, J2, J3, J4 | 0.66 | 0.023 | ..... | 0.955 |
| | | 639 | | 3.28 | 0.111 | ..... | 0.992 |
| | | 624 | | 6.43 | 0.215 | ..... | 1.039 |
| | | 755 | | 13.24 | 0.432 | ..... | 1.080 |
| | | 743 | | 13.64 | 0.447 | ..... | 1.100 |
| | | 685 | | 34.83 | 1.026 | ..... | 1.294 |
| | KK′ | 660 | K1, K2, K3, K4 | 0.87 | 0.028 | 39.41 | ..... |
| | | 637 | | 3.51 | 0.116 | 40.04 | 0.851 |
| | | 627 | | 6.03 | 0.194 | 40.85 | 0.888 |
| | | 754 | | 15.48 | 0.468 | 41.98 | 0.960 |
| | | 742 | | 16.57 | 0.495 | 42.07 | 0.968 |
| | | 705 | | 27.36 | 0.772 | 43.52 | ..... |
| | | 683 | | 30.88 | 0.858 | 44.12 | ..... |
| | LL′ | 659 | L1, L2, L3, L4 | 1.69 | 0.063 | 44.98 | 0.960 |
| | | 636 | | 4.09 | 0.149 | 45.28 | 1.025 |
| | | 625 | | 6.63 | 0.238 | 46.00 | 1.034 |
| | | 778 | | 12.02 | 0.408 | 45.60 | 1.154 |
| | | 777 | | 13.82 | 0.465 | 46.01 | 1.154 |
| | | 744 | | 15.14 | 0.505 | 46.13 | 1.180 |
| | | 704 | | 22.81 | 0.731 | 47.38 | 1.224 |
| | | 684 | | 25.27 | 0.793 | 47.37 | 1.197 |
| | MM′ | 661 | M1, M2, M3, M4 | 0.60 | 0.023 | 45.03 | ..... |
| | | 638 | | 3.30 | 0.121 | 45.40 | ..... |
| | | 745 | | 13.20 | 0.452 | 46.51 | ..... |
| | | 686 | | 27.19 | 0.850 | 48.12 | ..... |

Note.—In cases where the conductivity or density is omitted from the test results, the warping of the samples made the results of doubtful value.

### Density-Moisture and Conductivity-Moisture Relations

As previously stated, all of the species of wood were divided into six groups, and a representative species from each group was selected for determining the moisture-conductivity relation. From each of these representative species, four or more pairs of test panels were selected, and the conductivity and density of each pair were determined at several moisture contents covering the range from 0 to approximately the point of fiber saturation for the particular sample. In the earlier tests, a much wider range of moisture percentage was used, but for the later tests, those points above the fiber saturation were eliminated. The moisture contents of the samples were changed by placing them in a saturated atmosphere for a sufficient length of time to take up the required moisture. They were then wrapped in oil paper and left for periods of two weeks or longer to give the moisture an opportunity to equalize throughout the samples.

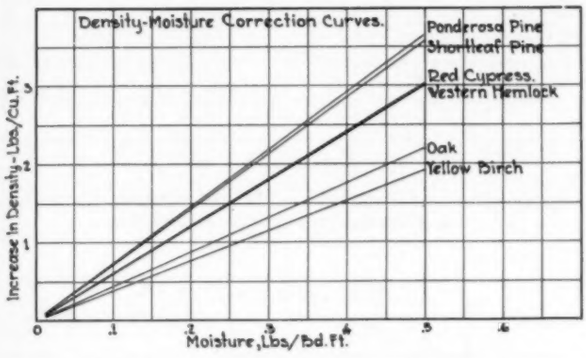



**Fig. 7—The relation between density and moisture content for the representative species as indicated**

In the denser wood, such as oak and birch, the higher moisture contents were accompanied by excessive warping of the boards. The condition was so bad in the oak group that it was necessary to run a large number of panels of both white oak and red oak in order to obtain satisfactory curves, two curves being taken from each group and averaged to give the final correction curve. No particular difficulty was experienced in conditioning the lighter species, and with these there was but little trouble experienced in warping during the tests.

The slopes of the several curves of each species were averaged to give the slope of the correction curve. This was done for both the moisture-conductivity and the density-moisture relation. The test results for the moisture-conductivity and the density-moisture relation are shown in the tabulated data of Table 1 and in the curve sheets, Figs. 1 to 6, inclusive.

The final results for density-moisture relations for the six species are shown on Fig. 7, and the final results for the conductivity-moisture relation are shown on Fig. 8.

From an examination of the density-moisture curve for the different species, it will be noted that in each case the test points lie substantially on a straight line, and, in general, the lines have the same slope for each species. There are, however, exceptions to this general rule.

Consider the case of Ponderosa Pine, Fig. 1. The lines from the data of Panels *LL'* and *XX'* have a steeper slope than the corresponding lines for Panels *HH'* and *KK'*. This indicates that, for the first two panels, the addition of moisture gives a higher rate of increase in density than for the second two panels. From this it would appear that the action of the moisture is different in the two cases, indicating that the rate of swelling or growth due to the measured moisture content in the specimen is different. An examination of the moisture-conductivity curve for Ponderosa Pine, Fig. 1, shows that the rate of increase in conductivity is greater for Panels *LL'* and *XX'* than it is for the other two panels. This general relation might be expected; yet it does not explain why there is a difference in the rate of density increase for different specimens with the same amount of moisture absorption. Considering the curve for yellow birch, Fig. 6, the relation between the conductivity-moisture curves does not definitely follow the relation between the density-moisture curves, although in this case the points on the moisture-conductivity curves are a little more scattered.

For Shortleaf Yellow Pine, the moisture-density curves, Fig. 3, are fairly uniform in slope, but the moisture-conductivity curve for Panel *JJ'* has a very much greater slope than for the other panels.

In the results obtained for West Coast Hemlock, Fig. 4, there is a close agreement between the slopes of the curves for both density-moisture and conductivity-moisture test results.

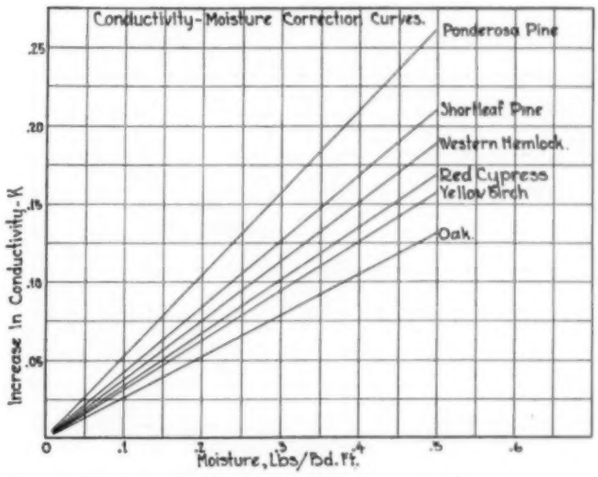



**Fig. 8—The relation between conductivity and moisture content for the representative species as indicated**

In general, it may be stated that the increase in density for the absorption of moisture is not at the same ratio for all specimens of the same species, and the conductivity-moisture relation is similar to the density-moisture relation for different samples of the same species.

By comparing the curves of Figs. 7 and 8, it will be observed that, in general, those species which have the greatest increase in density for a given increase in moisture also have the greatest increase in conductivity for a corresponding increase in moisture. Likewise, those species which are of lower density have the greatest rate

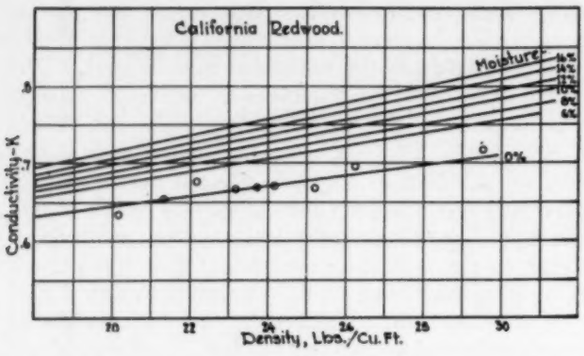



Fig. 9—California Redwood—Density-conductivity relation for different percentages of moisture

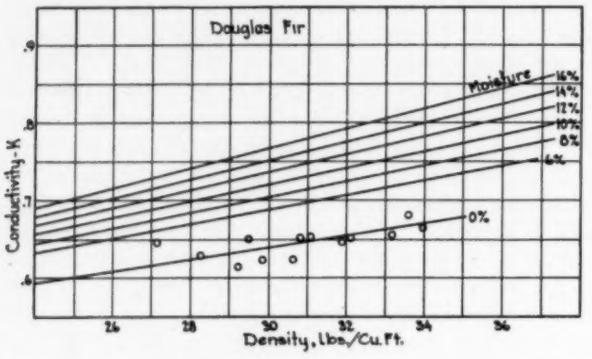



Fig. 10—Douglas Fir—Density-conductivity relation for different percentages of moisture

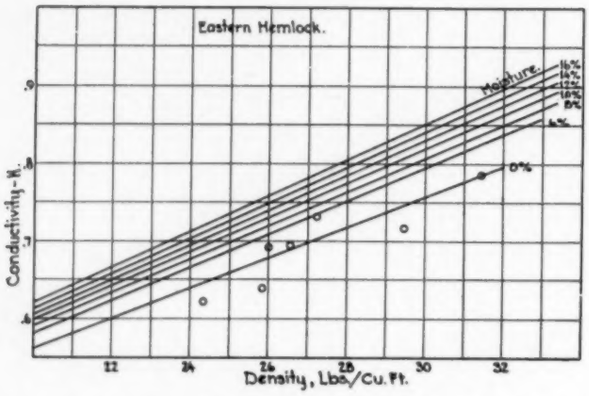



Fig. 11—Eastern Hemlock—Density-conductivity relation for different percentages of moisture

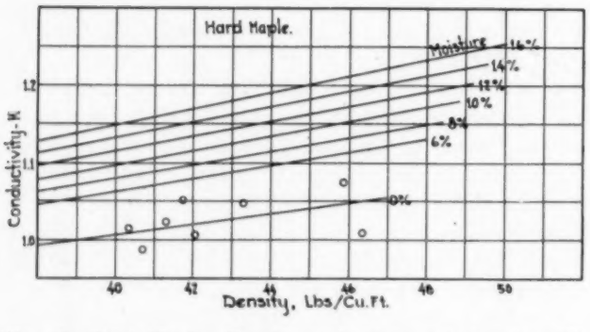



Fig. 12—Hard Maple—Density-conductivity relation for different percentages of moisture

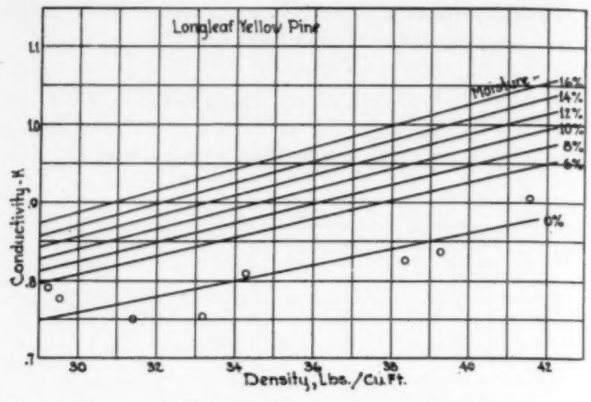



Fig. 13—Longleaf Yellow Pine—Density-conductivity relation for different percentages of moisture

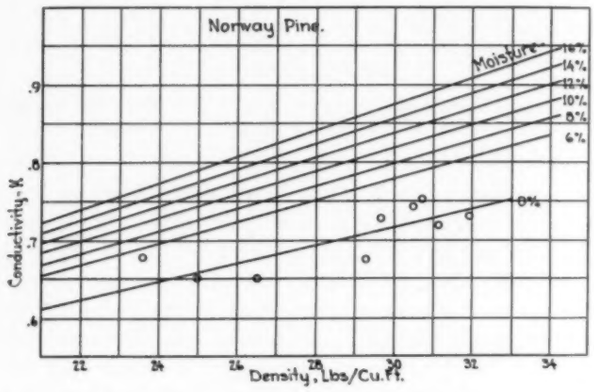



Fig. 14—Norway Pine—Density-conductivity relation for different percentages of moisture

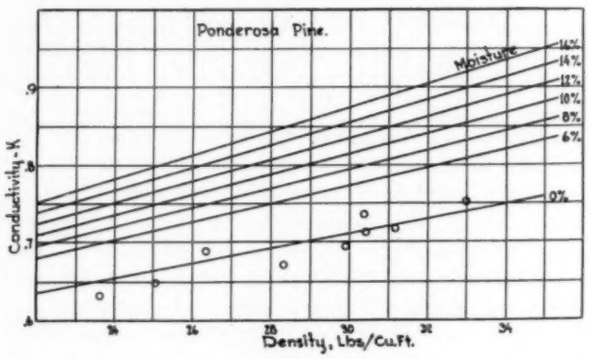



Fig. 15—Ponderosa Pine—Density-conductivity relation for different percentages of moisture

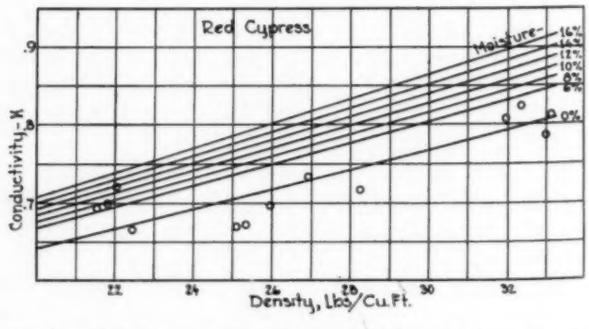



Fig. 16—Red Cypress—Density-conductivity relation for different percentages of moisture

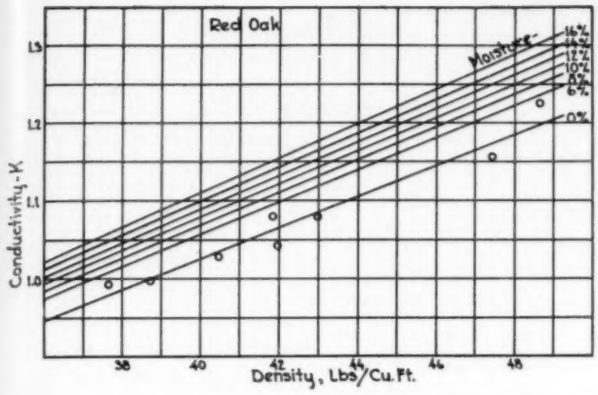



Fig. 17—Red Oak—Density-conductivity relation for different percentages of moisture

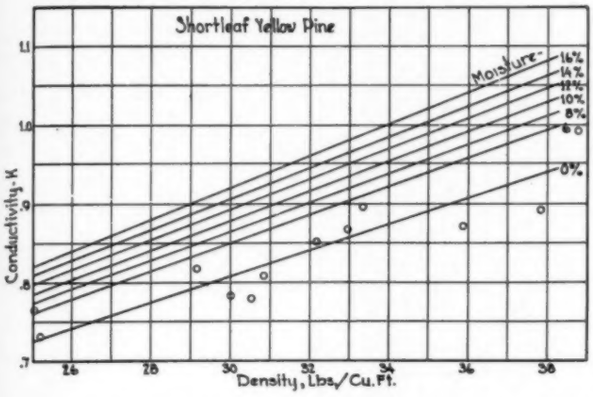



Fig. 18—Shortleaf Yellow Pine—Density-conductivity relation for different percentages of moisture

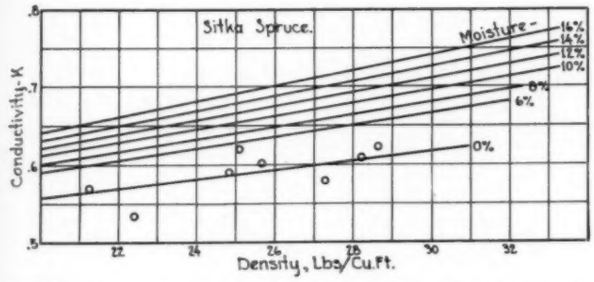



Fig. 19—Sitka Spruce—Density-conductivity relation for different percentages of moisture

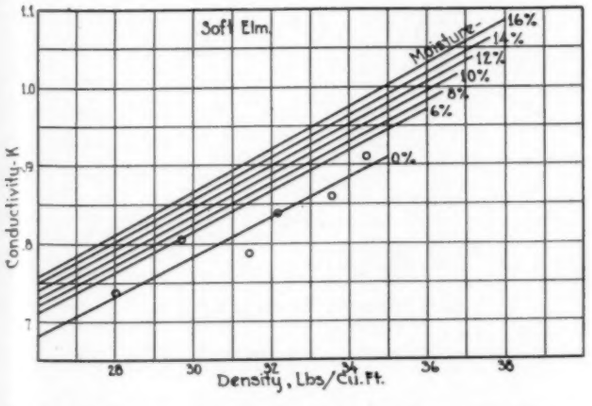



Fig. 20—Soft Elm—Density-conductivity relation for different percentages of moisture

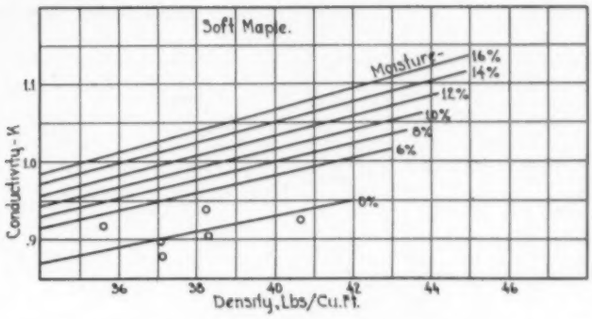



Fig. 21—Soft Maple—Density-conductivity relation for different percentages of moisture

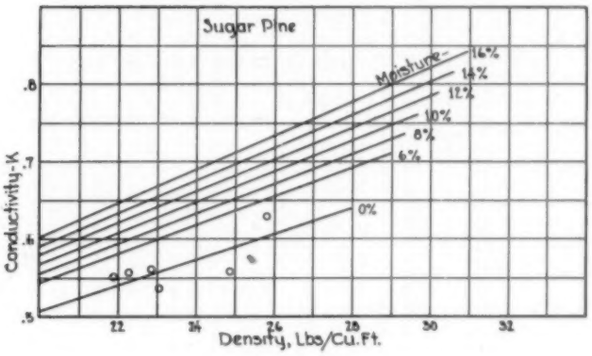



Fig. 22—Sugar Pine—Density-conductivity relation for different percentages of moisture

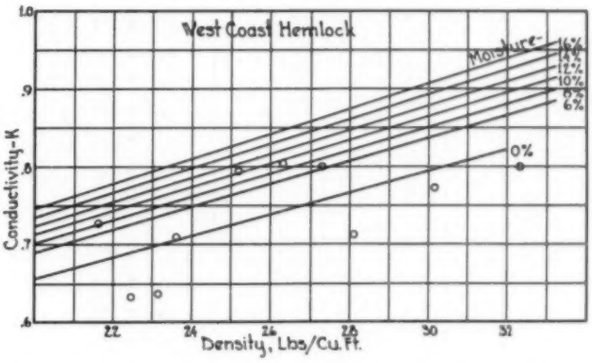



Fig. 23—West Coast Hemlock—Density-conductivity relation for different percentages of moisture

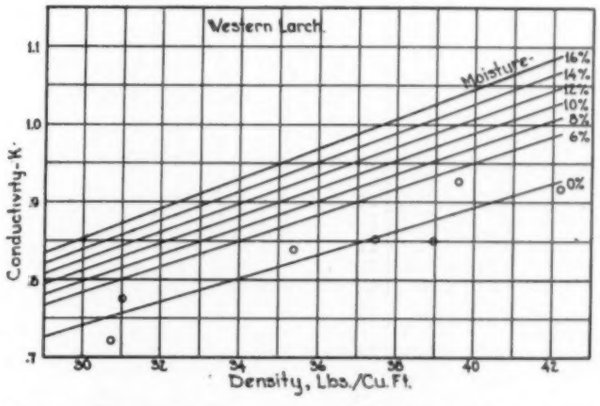



Fig. 24—Western Larch—Density-conductivity relation for different percentages of moisture

## Table 2—Test Data for Density-Conductivity Curves

Conductivities at 75 F Mean Temperature

| Species | Panels | Test No. | Composed of Boards | Density Lb/Cu Ft as Tested | Per Cent Moisture by Weight Dry Basis | Conductivity | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | As Tested | Corrected to 0 Per Cent Moisture | Corrected to 12 Per Cent Moisture |
| California Redwood | AA′ | 556 | L5, L6, L3, L11 | 20.67 | 4.92 | 0.661 | 0.634 | 0.700 |
| | BB′ | 395, 552 | L12, L2, L10, L8 | 22.00 | 6.30 | 0.690 | 0.653 | 0.723 |
| | CC′ | 551A | L7, L9, M6, M3 | 22.80 | 5.48 | 0.709 | 0.676 | 0.749 |
| | DD′ | 426, 581 | M5, M12, M1, M4 | 23.91 | 6.09 | 0.705 | 0.666 | 0.743 |
| | EE′ | 427 | M11, L4, M2, M7 | 24.51 | 7.06 | 0.713 | 0.667 | 0.746 |
| | FF′ | 428 | H2, H3, H12, H6 | 24.95 | 6.63 | 0.713 | 0.670 | 0.747 |
| | HH′ | 431 | H7, H1, M9, L1 | 26.06 | 6.67 | 0.713 | 0.667 | 0.750 |
| | JJ′ | 433, 537, 539, 542, 544 | M8, M10, H4, H5 | 27.05 | 5.75 | 0.738 | 0.695 | 0.784 |
| | KK′ | 432, 557, 15 | H8, H10, H9, H11 | 30.45 | 6.50 | 0.768 | 0.716 | 0.813 |
| Douglas Fir | *AB | 58 | A, B | 31.67 | 10.75 | 0.733 | 0.625 | 0.746 |
| | *AC | 59 | A, C | 31.31 | 10.75 | 0.758 | 0.651 | 0.771 |
| | *BC | 60 | B, C | 35.22 | 10.75 | 0.777 | 0.657 | 0.791 |
| | *DE | 61 | D, E | 32.91 | 10.14 | 0.761 | 0.654 | 0.780 |
| | *DF | 62 | D, F | 30.98 | 10.52 | 0.720 | 0.616 | 0.734 |
| | *EF | 63 | E, F | 34.01 | 10.28 | 0.764 | 0.653 | 0.783 |
| | *GH | 64 | G, H | 36.05 | 10.87 | 0.790 | 0.666 | 0.803 |
| | *GI | 65 | G, I | 33.86 | 10.87 | 0.764 | 0.648 | 0.776 |
| | *HI | 66 | H, I | 32.56 | 10.87 | 0.738 | 0.625 | 0.749 |
| | AA′ | 917 | D1, D2, D3, I4 | 29.19 | 5.62 | 0.685 | 0.631 | 0.747 |
| | BB′ | 918 | I1, F2, F3, F4 | 31.89 | 5.93 | 0.716 | 0.653 | 0.780 |
| | DD′ | 920 | B4, E3, H3, H4 | 34.68 | 5.56 | 0.746 | 0.682 | 0.820 |
| | LL | 598 | A4, A3, A1, D2, I4 | 28.08 | 6.53 | 0.707 | 0.647 | 0.756 |
| Eastern Hemlock | AA′ | 632 | B3, B2, B4, C1 | 32.47 | 7.06 | 0.851 | 0.784 | 0.899 |
| | BB′ | 629 | C2, C4, C3, B1 | 30.49 | 7.17 | 0.780 | 0.716 | 0.824 |
| | CC′ | 811 | A3, A4, D1, E4 | 28.22 | 7.63 | 0.754 | 0.731 | 0.831 |
| | DD′ | 628 | D2, A1, A2, D3 | 27.44 | 6.76 | 0.749 | 0.694 | 0.791 |
| | EE′ | 631 | D4, F1, E3, F2 | 26.92 | 7.18 | 0.748 | 0.691 | 0.786 |
| | FF′ | 633 | F4, J1, F3, I2 | 26.72 | 6.92 | 0.693 | 0.638 | 0.733 |
| | GG′ | 820 | I3, H3, E2, I4 | 25.41 | 7.37 | 0.696 | 0.621 | 0.710 |
| | HH′ | 814 | G1, G2, H1, H2 | 23.47 | 6.89 | 0.706 | 0.665 | 0.748 |
| Hard Maple | AA′ | 646 | A2, D3, D2, A1 | 42.03 | 5.63 | 1.082 | 1.023 | 1.148 |
| | BB′ | 855 | B1, B2, B3, B4 | 47.17 | 6.08 | 1.110 | 1.010 | 1.150 |
| | CC′ | 645 | C1, C2, C3, C4 | 46.72 | 6.10 | 1.146 | 1.075 | 1.214 |
| | EE′ | 650 | E1, E2, E3, E4 | 44.14 | 6.11 | 1.115 | 1.048 | 1.179 |
| | FF′ | 859 | F1, F2, F3, F4 | 42.44 | 6.03 | 1.108 | 1.051 | 1.177 |
| | GG′ | 652 | G1, G2, G3, G4 | 41.16 | 6.57 | 1.104 | 1.016 | 1.137 |
| | HH′ | 649 | H1, H2, H3, H4 | 41.45 | 5.87 | 1.048 | 0.987 | 1.111 |
| | II′ | 858 | I1, I2, I3, I4 | 42.89 | 5.99 | 1.077 | 1.007 | 1.135 |
| Longleaf Yellow Pine | AA′ | 508, 354, 13, 568 | B4, B3, C4, C3 | 43.11 | 6.58 | 0.999 | 0.906 | 1.076 |
| | CC′ | 507 | E1, E2 | 41.03 | 7.66 | 0.939 | 0.836 | 0.993 |
| | DD′ | 559, 511 | C1, E3 | 39.96 | 7.14 | 0.920 | 0.826 | 0.983 |
| | EE′ | 503, 558, 569 | D3, D4 | 35.60 | 6.57 | 0.887 | 0.810 | 0.951 |
| | FF′ | 510, 555 | F2, F3 | 34.47 | 6.65 | 0.829 | 0.754 | 0.889 |
| | GG′ | 506, 553 | I3, I4 | 32.59 | 6.31 | 0.817 | 0.749 | 0.879 |
| | HH′ | 504 | G2, G3 | 30.78 | 7.39 | 0.850 | 0.776 | 0.896 |
| | II′ | 505 | H2, G1 | 30.49 | 7.47 | 0.865 | 0.791 | 0.919 |
| Norway Pine | AA′ | 608 | B5, B1, B2, B3 | 33.18 | 6.75 | 0.823 | 0.732 | 0.894 |
| | BB′ | 821 | E1, E2, E3, E4 | 32.30 | 6.35 | 0.804 | 0.720 | 0.878 |
| | CC′ | 795 | A3, C2, C3, C5 | 32.00 | 7.05 | 0.845 | 0.753 | 0.910 |
| Norway Pine | DD′ | 604 | A1, A2, D5, F3 | 31.56 | 5.87 | 0.820 | 0.743 | 0.899 |
| | EE′ | 607 | A5, C1, D4, D1 | 30.81 | 6.49 | 0.811 | 0.729 | 0.880 |
| | FF′ | 609 | D2, D3, F1, F2 | 30.38 | 6.20 | 0.757 | 0.677 | 0.827 |
| | GG′ | 601 | H1, I5, H2, H3 | 27.53 | 6.39 | 0.722 | 0.650 | 0.786 |
| | HH′ | 602 | H4, I2, I3, H5 | 25.93 | 6.38 | 0.720 | 0.652 | 0.780 |
| | II′ | 604 | G2, G3, G4, G5 | 24.44 | 6.08 | 0.739 | 0.678 | 0.799 |
| Ponderosa Pine | AA′ | 526 | B4, B5, A3, A4 | 34.67 | 8.83 | 0.876 | 0.753 | 0.920 |
| | BB′ | 548A | B3, A2, E1, E2 | 32.79 | 8.90 | 0.835 | 0.719 | 0.876 |
| | CC′ | 807 | A1, E3, B2, E4 | 31.35 | 8.19 | 0.800 | 0.696 | 0.848 |
| | DD′ | 823 | B1, C5, C4, C3 | 29.40 | 6.32 | 0.749 | 0.672 | 0.813 |
| | EE′ | 808 | C2, C1, H1, D1 | 27.59 | 8.05 | 0.779 | 0.689 | 0.823 |
| | FF′ | 525 | F1, G3, G4, I1 | 26.35 | 8.63 | 0.740 | 0.649 | 0.776 |
| | GG′ | 546 | D2, D3, D4, D5 | 26.35 | 9.11 | 0.744 | 0.648 | 0.774 |
| | HH′ | 545 | H3, H4, H5, I3 | 24.83 | 8.73 | 0.718 | 0.631 | 0.751 |
| | JJ′ | 391 | J1, J2, J3, J4 | 31.52 | 6.02 | 0.792 | 0.713 | 0.870 |
| | KK′ | 392 | K1, K2, K3, K4, K5 | 31.42 | 5.68 | 0.810 | 0.751 | 0.876 |
| | LL′ | 387 | L1, L2, L3, L4 | 26.54 | 10.75 | 0.815 | 0.725 | 0.825 |
| | XX′ | 430 | J1, J3, K1, K2, K3, K4, L1, L2, L3, L4 | 29.68 | 9.88 | 0.827 | 0.734 | 0.847 |
| Red Cypress | *AB | 90 | A1, A2, A3, A4, A5, B1, B2, B3, B4, B5 | 26.91 | 7.35 | 0.749 | 0.697 | 0.782 |
| | *AC | 98 | A1, A5, C1, C5 | 26.20 | 7.08 | 0.721 | 0.672 | 0.755 |
| | *BC | 94 | B1, B5, C1, C5 | 27.81 | 6.79 | 0.785 | 0.735 | 0.823 |
| | *DE | 95 | D1, D5, E1, E5 | 33.01 | 6.97 | 0.870 | 0.809 | 0.913 |
| | *DF | 97 | D1, D5, F1, F5 | 34.07 | 6.57 | 0.847 | 0.788 | 0.896 |
| | *EF | 96 | E1, E5, F1, F5 | 34.29 | 7.27 | 0.878 | 0.813 | 0.921 |
| | *GH | 99 | G1, G5, H1, H5 | 22.27 | 6.95 | 0.734 | 0.693 | 0.763 |
| | *GI | 100 | G1, G5, I1, I5 | 22.79 | 6.84 | 0.761 | 0.720 | 0.792 |
| | *HI | 101 | H1, H5, I1, I5 | 22.54 | 6.98 | 0.742 | 0.700 | 0.772 |
| | AA′ | 923 | G1, I2, I4, I5, H4 | 23.01 | 5.28 | 0.697 | 0.665 | 0.739 |
| | BB′ | 924 | A2, A3, A4, C2, C3 | 25.79 | 5.58 | 0.709 | 0.670 | 0.753 |
| | DD′ | 927 | B1, B3, B4, B5, E2 | 28.88 | 4.60 | 0.753 | 0.717 | 0.811 |
| | EE′ | 928 | D1, D2, D2, D3, E2 | 33.05 | 4.38 | 0.865 | 0.826 | 0.934 |
| Red Oak | AA′ | 549A | C1, C1, C2, C2 | 49.60 | 5.43 | 1.280 | 1.224 | 1.347 |
| | BB′ | 492, 576 | B2, B2, B3, B3 | 48.45 | 5.81 | 1.214 | 1.156 | 1.277 |
| | CC′ | 495, 577 | D3, D2, D3, G1 | 43.96 | 6.37 | 1.137 | 1.079 | 1.188 |
| | DD′ | 854 | G2, G2, G3, G3 | 42.89 | 7.07 | 1.142 | 1.080 | 1.185 |
| | EE′ | 496 | D1, D2, D1, G1 | 42.82 | 6.71 | 1.093 | 1.042 | 1.140 |
| | FF′ | 494, 575 | A2, A2, A3, A3 | 41.28 | 5.58 | 1.076 | 1.028 | 1.131 |
| | GG′ | 550A | A1, I2, I3, I3 | 39.51 | 5.76 | 1.045 | 0.998 | 1.096 |
| | HH′ | 498, 527, 529, 531 | H1, H3, I1, I2 | 38.43 | 5.87 | 1.040 | 0.993 | 1.089 |
| Shortlea Yellow Pine | AA′ | 436, 565 | A3, C1 | 40.35 | 7.24 | 1.086 | 0.990 | 1.148 |
| | BB′ | 437, 564 | A2, B3 | 39.18 | 6.13 | 0.971 | 0.892 | 1.047 |
| | CC′ | 441 | B2, C2 | 37.46 | 7.72 | 0.964 | 0.870 | 1.018 |
| | DD′ | 434, 14 | D3, D1 | 34.16 | 6.33 | 0.937 | 0.866 | 1.001 |
| | EE′ | 442 | E2, E1 | 30.30 | 6.72 | 0.883 | 0.816 | 0.936 |
| | FF′ | 435, 567 | F2, F3 | 34.51 | 5.88 | 0.960 | 0.893 | 1.031 |

* Panels tested on the 24-inch hot plate.

**Table 2—Test Data for Density-Conductivity Curves—Continued**

| Species | Panels | Test No. | Composed of Boards | Density Lb/Cu Ft as Tested | Per Cent Moisture by Weight Dry Basis | Conductivity | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | As Tested | Corrected to 0 Per Cent Moisture | Corrected to 12 Per Cent Moisture |
| Shortleaf Yellow Pine | GG′ | 445, 570 | G2, G3... | 25.64 | 5.90 | 0.795 | 0.745 | 0.847 |
| | HH′ | 562 | H1, H3... | 25.72 | 4.55 | 0.803 | 0.764 | 0.867 |
| | II′ | 455, 572 | I1, I2.... | 26.12 | 6.04 | 0.786 | 0.732 | 0.839 |
| | JJ′ | 757 | J2, J3, K3, L3..... | 31.76 | 6.85 | 0.851 | 0.779 | 0.905 |
| | KK′ | 390 | J1, K1, K2, K3.... | 33.42 | 6.64 | 0.923 | 0.851 | 0.983 |
| | LL′ | 804 | L1, L1, L2, J2..... | 31.21 | 6.83 | 0.854 | 0.784 | 0.907 |
| | XX′ | 429 | J1, J3, K1, K2, L2, L3..... | 32.03 | 6.75 | 0.877 | 0.807 | 0.932 |
| Sitka Spruce | BB′ | 477, 579 | A1, C1, C2, C3.... | 29.50 | 6.26 | 0.677 | 0.623 | 0.727 |
| | CC′ | 475, 580 | A4, B1, B2, B3.... | 28.10 | 6.26 | 0.630 | 0.578 | 0.678 |
| | DD′ | 935 | A2, A3, B4 | 29.09 | 6.36 | 0.664 | 0.609 | 0.713 |
| | FF′ | 937 | G4, H1, H2, I1, I2, I3.. | 26.45 | 6.55 | 0.652 | 0.601 | 0.695 |
| | GG′ | 473, 11, 12 | F4, G1, G2, G3..... | 25.78 | 6.01 | 0.665 | 0.619 | 0.711 |
| | HH′ | 938 | H2, I1, I2, I3..... | 25.57 | 6.35 | 0.638 | 0.590 | 0.681 |
| | JJ′ | 467, 19 | J1, J2, J3, J4..... | 23.10 | 6.58 | 0.579 | 0.534 | 0.616 |
| | KK′ | 474, 20 | K1, K2, K3, K4 | 21.93 | 6.93 | 0.614 | 0.569 | 0.647 |
| Soft Elm | AA′ | 523 | E4, D2, D3, F3.. | 35.26 | 7.67 | 0.976 | 0.910 | 1.013 |
| | BB′ | 797 | B3, C4, D1, E3. | 34.52 | 7.29 | 0.920 | 0.859 | 0.960 |
| | CC′ | 518 | C3, D4, I1, A4..... | 32.91 | 7.58 | 0.900 | 0.839 | 0.935 |
| | DD′ | 520 | A1, A2, A3, C2..... | 32.27 | 7.83 | 0.854 | 0.787 | 0.890 |
| | EE′ | 519 | H3, H4, I3, | 30.39 | 7.51 | 0.860 | 0.805 | 0.894 |
| | FF′ | 521 | 14, G1, G2, G3, H2. | 28.61 | 7.18 | 0.787 | 0.737 | 0.821 |
| Soft Maple | AA′ | 694 | A4, G4, A3, A1. | 39.03 | 6.03 | 0.962 | 0.904 | 1.020 |
| | DD′ | 696 | D1, D2, D3, D4. | 36.33 | 6.54 | 0.976 | 0.917 | 1.024 |
| | EE′ | 698 | E1, E2, E3, E4..... | 37.83 | 6.07 | 0.936 | 0.879 | 0.991 |
| | FF′ | 653 | F1, F3, B4, C1..... | 37.77 | 6.04 | 0.952 | 0.896 | 1.008 |
| | GG′ | 697 | G1, G2, G3, H4. | 38.98 | 6.33 | 0.999 | 0.938 | 1.054 |
| | II′ | 695 | I1, I2, I3, I4..... | 41.41 | 6.12 | 0.988 | 0.925 | 1.048 |
| Sugar Pine | AA′ | 500, 586 | D1, D2, D4, F2. | 27.09 | 8.44 | 0.721 | 0.629 | 0.760 |
| | BB′ | 815 | F3, G3, G2, G4..... | 26.12 | 8.43 | 0.648 | 0.559 | 0.686 |
| | CC′ | 499, 22 | E1, H2, H3, H4. | 24.22 | 8.60 | 0.621 | 0.537 | 0.654 |
| | DD′ | 502, 563 | E2, E4, I3, E3..... | 23.96 | 8.27 | 0.642 | 0.562 | 0.678 |
| | EE′ | 503, 583 | B1, B2, B3, B4..... | 23.38 | 8.34 | 0.636 | 0.557 | 0.670 |
| | FF′ | 501 | A3, C1, C2, C3..... | 23.08 | 8.86 | 0.634 | 0.552 | 0.663 |
| West Coast Hemlock | AA′ | 465, 574 | A2, A3, A4, B1..... | 33.18 | 5.58 | 0.755 | 0.700 | 0.819 |
| | BB′ | 462 | A5, B2, B4, B5..... | 31.07 | 6.42 | 0.732 | 0.673 | 0.784 |
| | FF′ | 463, 538, 560 | B3, F1, F2, F3..... | 28.98 | 6.32 | 0.667 | 0.613 | 0.716 |
| | GG′ | 460, 540, 10 | G1, G2, G3, G4. | 27.06 | 5.84 | 0.752 | 0.704 | 0.803 |
| | HH′ | 476, 561 | H2, H3, H4, H5.. | 23.90 | 6.81 | 0.585 | 0.537 | 0.622 |
| | II′ | 461, 17 | I2, I3, I4, I5..... | 23.14 | 6.19 | 0.576 | 0.533 | 0.616 |
| | JJ′ | 666 | J2, K5, L4, L2..... | 24.36 | 5.38 | 0.657 | 0.610 | 0.716 |
| | KK′ | 664 | K5, K4, J3, K3. | 22.32 | 5.30 | 0.669 | 0.627 | 0.723 |
| | LL′ | 663 | L2, M1, L3, M2. | 28.28 | 6.18 | 0.761 | 0.699 | 0.820 |
| | MM′ | 665 | L4, M5, M3, M4 | 26.53 | 9.04 | 0.779 | 0.694 | 0.806 |
| Western Larch | AA′ | 458 | A3, C3, C4, F3..... | 44.62 | 10.00 | 1.059 | 0.917 | 1.088 |
| | BB′ | 454 | A2, C5, D5, F4..... | 41.86 | 9.66 | 1.059 | 0.926 | 1.092 |
| | CC′ | 449 | A4, B2, C2, D4..... | 41.28 | 10.46 | 0.985 | 0.848 | 1.006 |
| | DD′ | 450 | B4, D3, G2, H5, | 39.68 | 10.30 | 0.986 | 0.857 | 1.008 |
| Western Larch | KE′ | 448 | D2, F5, G3, H2..... | 37.50 | 10.30 | 0.962 | 0.839 | 0.982 |
| | FF′ | 451 | I1, I2, I3, C5..... | 32.95 | 10.81 | 0.889 | 0.775 | 0.901 |
| | GG′ | 459 | E1, E2, E3, E4..... | 32.81 | 10.61 | 0.831 | 0.721 | 0.845 |
| Western Red Cedar | *AB | 67 | A, B..... | 26.40 | 11.00 | 0.774 | 0.700 | 0.781 |
| | *AC | 68 | A, C..... | 25.09 | 11.58 | 0.700 | 0.627 | 0.703 |
| | *DE | 70 | D, E..... | 22.50 | 10.15 | 0.617 | 0.558 | 0.627 |
| | *DF | 69 | D, F..... | 22.62 | 9.97 | 0.616 | 0.558 | 0.628 |
| | *EF | 71 | E, F..... | 22.80 | 9.70 | 0.612 | 0.555 | 0.625 |
| | *GH | 79 | G, H..... | 21.82 | 8.25 | 0.603 | 0.556 | 0.624 |
| | *GI | 80 | G, I..... | 21.86 | 8.14 | 0.560 | 0.514 | 0.582 |
| | *HI | 78 | H, I..... | 22.31 | 8.46 | 0.604 | 0.555 | 0.625 |
| | HH′ | 951 | A4, A2, A3, A1, A3. | 28.29 | 5.05 | 0.817 | 0.779 | 0.870 |
| | LL′ | 595 | C4, G2, G2, G4, G3.... | 20.70 | 6.43 | 0.585 | 0.550 | 0.616 |
| White Ash | AA′ | 592 | A1, B1, B2, F1..... | 45.98 | 8.59 | 1.163 | 1.084 | 1.195 |
| | BB′ | 470 | A1, A2, A2, A3..... | 45.42 | 9.73 | 1.123 | 1.035 | 1.144 |
| | DD′ | 482, 593 | B4, E1, E1, E3..... | 42.40 | 8.81 | 1.019 | 0.944 | 1.046 |
| | EE′ | 484, 594 | B3, E6, F3, I1..... | 41.82 | 8.46 | 1.055 | 0.984 | 1.085 |
| | FF′ | 478 | I2, H2, H3, E5..... | 38.67 | 8.66 | 0.939 | 0.872 | 0.965 |
| | GG′ | 480 | E5, I2, I3, H1..... | 38.20 | 8.56 | 1.021 | 0.955 | 1.047 |
| | HH′ | 481 | E2, E2, G2, G2..... | 32.14 | 8.13 | 0.908 | 0.855 | 0.933 |
| White Fir | *AB | 49 | A, B..... | 21.92 | 8.80 | 0.565 | 0.509 | 0.585 |
| | *AC | 50 | A, C..... | 22.37 | 8.28 | 0.573 | 0.519 | 0.597 |
| | *BC | 51 | B, C..... | 22.48 | 8.42 | 0.588 | 0.533 | 0.612 |
| | *DE | 52 | D, E..... | 23.38 | 8.50 | 0.594 | 0.536 | 0.618 |
| | *DF | 53 | D, F..... | 24.15 | 8.37 | 0.595 | 0.536 | 0.620 |
| | *EF | 54 | E, F..... | 25.32 | 8.49 | 0.626 | 0.564 | 0.652 |
| | *GH | 55 | G, H..... | 26.50 | 8.49 | 0.662 | 0.597 | 0.689 |
| | *GI | 56 | G, I..... | 25.10 | 8.60 | 0.656 | 0.593 | 0.681 |
| | *HI | 57 | H, I..... | 27.20 | 8.35 | 0.693 | 0.627 | 0.722 |
| White Oak | AA′ | 487, 23 | E1, E1, E2, E2..... | 51.35 | 6.75 | 1.244 | 1.173 | 1.300 |
| | BB′ | 483 | D2, D3, D3, D1. | 49.54 | 7.18 | 1.221 | 1.148 | 1.269 |
| | CC′ | 489, 588 | D1, D2, F3, H3. | 48.61 | 7.00 | 1.176 | 1.106 | 1.226 |
| | DD′ | 485, 589 | F1, F2, F2, H1..... | 44.03 | 7.26 | 1.180 | 1.114 | 1.222 |
| | EE′ | 488, 590 | G2, G2, G3, G3. | 42.79 | 6.74 | 1.136 | 1.077 | 1.183 |
| | FF′ | 486, 591 | I1, I1, I2, I2..... | 39.99 | 6.92 | 1.085 | 1.028 | 1.127 |
| Northern White Pine | AA′ | 612 | A3, A2, A1, A4..... | 32.40 | 6.25 | 0.880 | 0.797 | 0.957 |
| | BB′ | 617 | A5, C3, C4, C2..... | 31.28 | 6.78 | 0.911 | 0.824 | 0.978 |
| | CC′ | 616 | E1, E2, E3, E4..... | 27.95 | 6.24 | 0.758 | 0.686 | 0.824 |
| | DD′ | 614 | E5, B3, B4, D5..... | 26.84 | 6.93 | 0.795 | 0.719 | 0.851 |
| | EE′ | 611 | B1, B2, C1, F4..... | 26.79 | 6.65 | 0.794 | 0.721 | 0.853 |
| | FF′ | 615 | F5, B5, F2, F3..... | 21.47 | 6.55 | 0.704 | 0.638 | 0.758 |
| | GG′ | 618 | F1, G4, G5, I2..... | 23.87 | 6.14 | 0.657 | 0.597 | 0.715 |
| | HH′ | 622 | D3, D1, G3, I1.. | 23.01 | 6.54 | 0.662 | 0.600 | 0.714 |
| | II′ | 613 | H1, H2, H3, H4. | 21.02 | 6.32 | 0.663 | 0.608 | 0.711 |
| Yellow Birch | AA′ | 515 | B1, B2, B3, C2..... | 45.34 | 9.71 | 1.022 | 0.917 | 1.047 |
| | BB′ | 514 | F1, F2, F3, F4..... | 43.94 | 9.14 | 1.005 | 0.909 | 1.035 |
| | CC′ | 512 | I1, I2, I4, H2..... | 41.54 | 9.20 | 0.960 | 0.868 | 0.988 |
| | DD′ | 516 | G1, G2, G3, H1. | 39.81 | 9.28 | 0.985 | 0.896 | 1.011 |
| | EE′ | 513 | E2, E3, D3, G4. | 38.82 | 9.49 | 0.856 | 0.769 | 0.979 |
| | FF′ | 890 | E1, D1, D2, D4. | 37.73 | 9.84 | 0.926 | 0.837 | 0.945 |
| | KK′ | 627 | K1, K2, K3, K4. | 40.85 | 6.03 | 0.888 | 0.827 | 0.949 |
| | LL′ | 625 | L1, L2, L3, L4..... | 46.00 | 6.63 | 1.034 | 0.959 | 1.095 |

*Panels tested on the 24-inch hot plate.

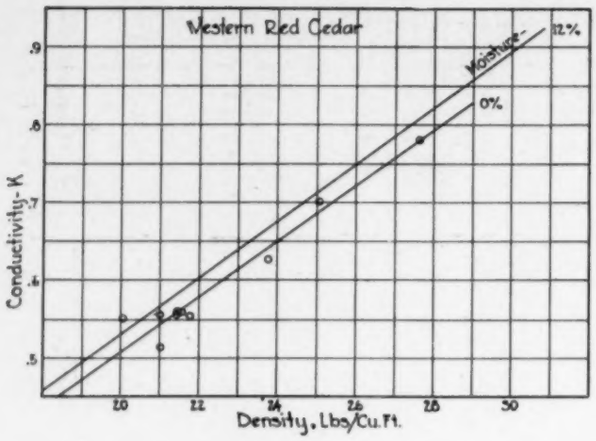



Fig. 25—Western Red Cedar—Density-conductivity relation for different percentages of moisture

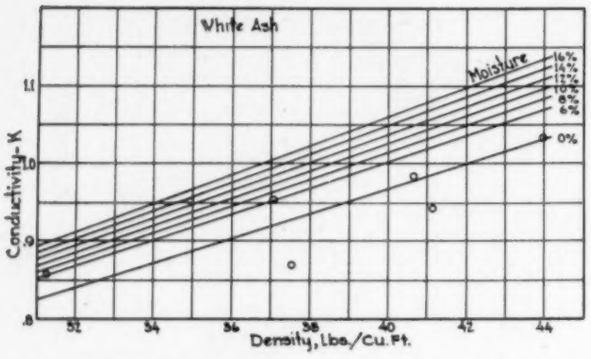



Fig. 26—White Ash—Density-conductivity relation for different percentages of moisture

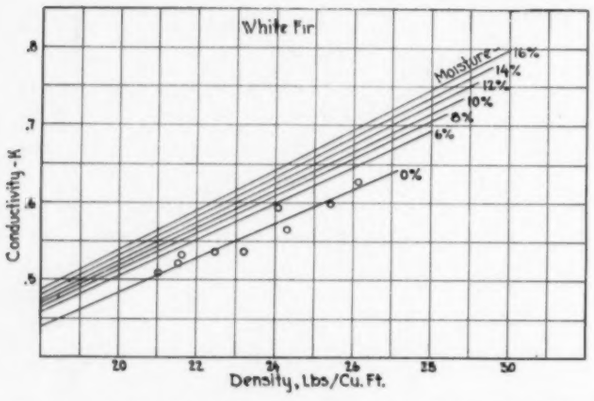



Fig. 27—White Fir—Density-conductivity relation for different percentages of moisture

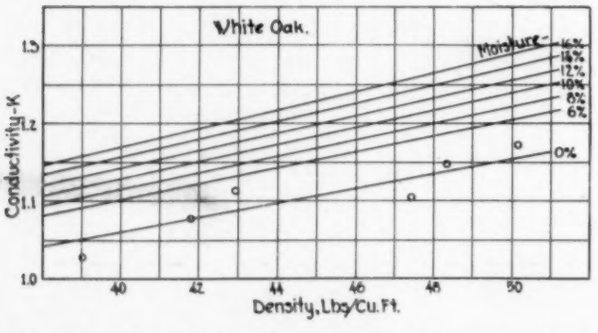



Fig. 28—White Oak—Density-conductivity relation for different percentages of moisture

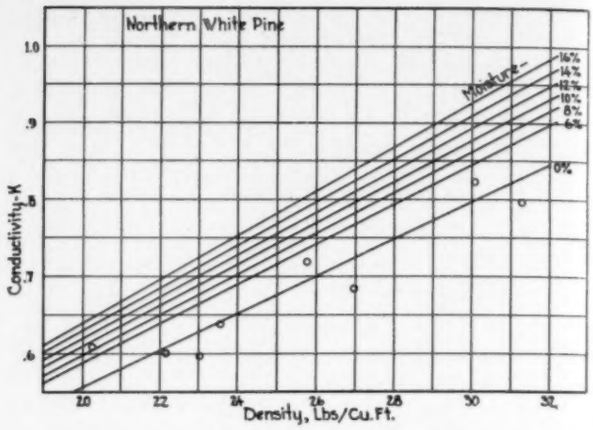



Fig. 29—Northern White Pine—Density-conductivity relation for different percentages of moisture

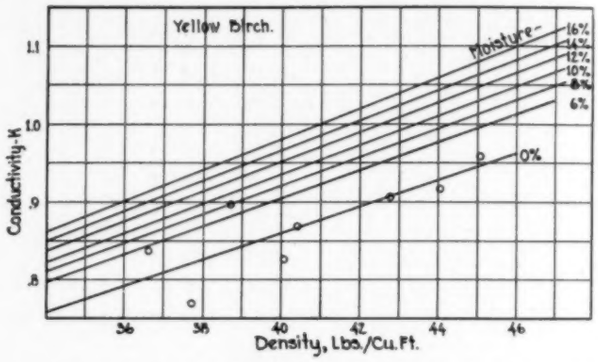



Fig. 30—Yellow Birch—Density-conductivity relation for different percentages of moisture

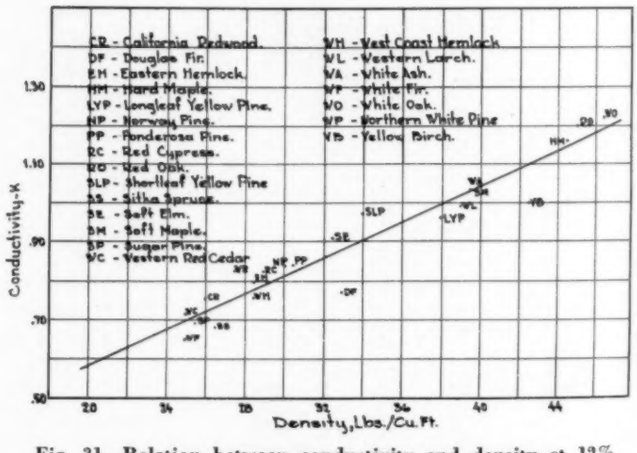

CR - California Redwood.
DF - Douglas Fir.
EH - Eastern Hemlock.
HM - Hard Maple.
LYP - Longleaf Yellow Pine.
NP - Norway Pine.
PP - Ponderosa Pine.
RC - Red Cypress.
RO - Red Oak.
SLP - Shortleaf Yellow Pine
SS - Sitka Spruce.
SE - Soft Elm.
SM - Soft Maple.
SP - Sugar Pine.
WC - Western Red Cedar
WH - West Coast Hemlock
WL - Western Larch.
WA - White Ash.
WP - White Pine.
WO - White Oak.
WP - Northern White Pine
YB - Yellow Birch.
Conductivity - K
Density, Lbs./Cu. Ft.

Fig. 31—Relation between conductivity and density at 12% moisture for average densities of species as tested

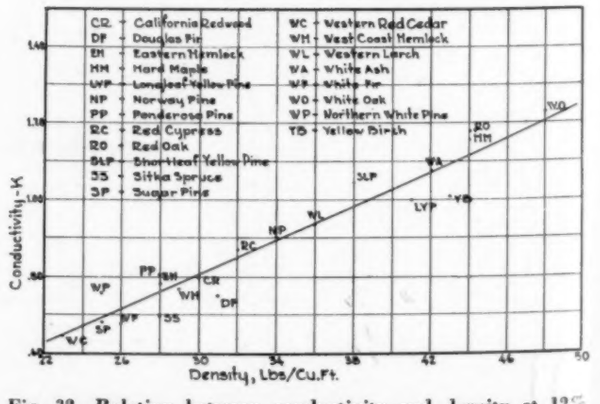

CR + California Redwood
DF + Douglas Fir
EH + Eastern Hemlock
HM + Hard Maple
LYP + Longleaf Yellow Pine
NP + Norway Pine
PP + Ponderosa Pine
RC + Red Cypress
RO + Red Oak
SLP + Shortleaf Yellow Pine
SS + Sitka Spruce
SP + Sugar Pine
WC + Western Red Cedar
WH + West Coast Hemlock
WL + Western Larch
WA + White Ash
WP + White Pine
WO + White Oak
WP + Northern White Pine
YB + Yellow Birch
Conductivity - K
Density, Lbs/Cu. Ft.

Fig. 32—Relation between conductivity and density at 12% moisture for average densities as selected from Technical Bulletin No. 158, U. S. Department of Agriculture

of increase in density and conductivity when a given amount of moisture per board foot is added.

The density-moisture and conductivity-moisture curves as obtained for each representative species were used to convert the test results from other species of the group to results at different moisture contents as explained later.

### Conductivity-Density Relation

The conductivity-density relations as determined by the tests for the various species are shown in the curve sheets, Figs. 9 to 30, inclusive, and in the tabulated data of Table 2. For each species, the conductivities were obtained for the different densities at moisture content as received which varied from 4½ per cent to 11 per cent. The per cent moisture as tested is shown in the tabulated data. The thermal conductivity and density values obtained in the tests were corrected to 0 per cent moisture and plotted on the curve sheets, Figs. 9 to 30, inclusive. The conductivity curve for 0 per cent moisture was drawn and the values from this curve were used to determine the other conductivity values ranging up to 16 per cent moisture.

In making the corrections in conductivity and density for 0 per cent moisture, the curves for moisture-density and moisture-conductivity, Figs. 7 and 8, were taken as determined for the species which was used as the representative of the particular material under test. From the density-moisture curve, the density at 0 per cent moisture was determined, and from the conductivity-moisture curve the conductivity at 0 per cent moisture was determined, thus giving the coordinates for conductivity-density corresponding to the particular sample tested. The points for all tests were corrected in this manner, and the 0 per cent curve was drawn through these points by the method of least squares.

The points for the curves of higher percentages of moisture for a given species were calculated from the 0 per cent curve in the following manner: For a given density in pounds per cubic foot and a given moisture content, the weight of moisture in pounds per board foot was calculated. From this value, the increase in density in pounds per cubic foot was obtained from the representative species, Fig. 7. In like manner, the increase in conductivity for the calculated moisture content in pounds per board foot was determined from Fig. 8. These increases in density and conductivity were added to the density and conductivity values for the original selected point, and the new values plotted on the curve sheet as a new point on the conductivity-density relation for the given percentage of moisture.

Since these lines were plotted as straight lines, it is evident that the calculation of two points for each moisture content was sufficient. As has been previously stated, there might be some question about the accuracy of correcting the values for a group of materials by a curve derived from one of the group as representative. It should be pointed out, however, that the tests were made at moisture contents ranging from 6 to 10 per cent. Thus, if there was an error in correcting back to the 0 per cent moisture, this error would be eliminated in correcting the given point back to a percentage of moisture corresponding to test conditions.

In correlating the data of Tables 1 and 2 with the curve sheet, it should be observed that the moisture per cent by weight shown in the tables is given as the percentage by weight of the dry material in the specimen, whereas in the curves of Figs. 9 to 30, inclusive, the percentages of moisture are based upon the total weight per cubic foot and not on the dry material. Thus from the curves, the conductivity for any density and moisture content from 0 to 16 per cent may be read directly.

In order to get some comparison between the density-conductivity relation for the different species, curves on Figs. 31 and 32 were plotted. The points for Fig. 31 represent the conductivity at 12 per cent moisture for the average density of each species as tested. For Fig. 32 the points represent the conductivities as taken from the 12 per cent moisture lines, but the densities were the averages for each species as given in *Technical Bulletin* No. 158 of the U. S. Department of Agriculture. The densities used for the curves of Fig. 32 were as follows:

| Species | Density, lb per cu ft |
|---|---|
| California Redwood | 30 |
| Douglas Fir | 31 |
| Eastern Hemlock | 28 |
| Hard Maple | 44 |
| Longleaf Yellow Pine | 41 |
| Norway Pine | 34 |
| Ponderosa Pine | 28 |
| Red Cypress | 32 |
| Red Oak | 44 |
| Shortleaf Yellow Pine | 38 |
| Sitka Spruce | 28 |
| Sugar Pine | 25 |
| Western Red Cedar | 23 |
| West Coast Hemlock | 29 |
| Western Larch | 36 |
| White Ash | 42 |
| White Fir | 26 |
| White Oak | 48 |
| Northern White Pine | 25 |
| Yellow Birch | 43 |

By comparing the densities of the materials tested with the average densities taken from *Bulletin* No. 158, it will be noted that, in a majority of cases, the selected values fall within the range of test values; in a few cases, such as California Redwood, Norway Pine, Shortleaf Pine, Soft Elm, White Ash, and White Fir, the densities of the materials tested were of a lower average than those given in the bulletin. The final curves of density-conductivity relation, however, for the several species as shown in Figs. 31 and 32 are substantially the same.

The conductivity values for all species fall sufficiently close to the straight line to indicate that for practical purposes the straight line relation may be used when the moisture contents are the same.

In making these tests and preparing this report, acknowledgement is due Mr. Frank P. Cartwright, Chief Engineer of the *National Lumber Manufacturers' Association,* for his suggestions throughout the work, as well as for the initial selection and preparation of the samples; to Mr. A. B. Algren for his assistance in supervising the laboratory program; and to Messrs. W. A. Eckley and L. A. Clousing, who conducted the greater part of the tests by the hot plate method.

Pittsburgh Experiment Station of the U. S. Bureau of Mines where the Research Laboratory of the American Society of Heating and Ventilating Engineers is located

# Indices of Air Change and Air Distribution*

*By* F. C. Houghten† and J. L. Blackshaw,‡ Pittsburgh, Pa.
*MEMBERS*

VENTILATION engineers have for a number of years accepted the principle of analyzing air for carbon dioxide concentrations as a measure of the rate of air change, and of comparing these concentrations to measure the uniformity of air distribution throughout a ventilated space. Although investigators in carrying on original research have employed the $CO_2$ method to some extent, it has found little use by engineers in making routine ventilation surveys in schools and audience halls because of the difficulties involved in obtaining representative samples of the air in a room, in preserving these samples during their transportation to a laboratory for subsequent analysis, and in the extremely precise laboratory determination that is necessary to measure with sufficient accuracy the small quantity of $CO_2$ in the sample.

Recently, there was written into the *Code of Ventilation Standards* of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS a section approving the use of the $CO_2$ method as a measure of air distribution. Questions arose concerning the desirability of having, in a Code to be universally applied, a standard which is so little used. As a result, it was suggested that the Research Laboratory make an analysis and comparison of the $CO_2$ method and other methods of measuring air change and air distribution.

An occupant of an enclosed space changes the physical and chemical composition of the air contained therein in several ways. Any of these changes might be used as a measure of ventilation, but the three most adaptable are: the increase in the sensible heat content of the air; the increase in the moisture content of the air and therefore its latent heat content; and the increase in the $CO_2$ content of the air.

## Air Change Indices

Data[1] published by the Research Laboratory of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, as well as results of other investigations, show that an average size man seated at rest in an audience hall, under ordinary temperatures, dissipates to the atmosphere 0.59 cu ft of $CO_2$ per hour, and also definite quantities of sensible heat and moisture which vary with the dry-bulb temperature of the air according to established relationships. Based on this $CO_2$ dissipation rate and on sensible and latent heat dissipation rates varying with temperature in accordance with accepted curves[2] from Research Laboratory data on heat and moisture losses from men at rest and at work, the curves in Fig. 1 show the effect of a man on the air in an enclosed space, assuming all of the $CO_2$, moisture, and heat added

*For presentation at the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Hotel Statler, Detroit, Mich., June, 1933.

†Director, A. S. H. V. E. Research Laboratory.

‡Research Engr., Research Laboratory.

[1]Heat and Moisture Losses from The Human Body and Their Relation to Air Conditioning Problems, by F. C. Houghten, W. W. Teague, W. E. Miller and W. P. Yant. A. S. H. V. E. TRANSACTIONS, Vol. 35, 1929, p. 245.

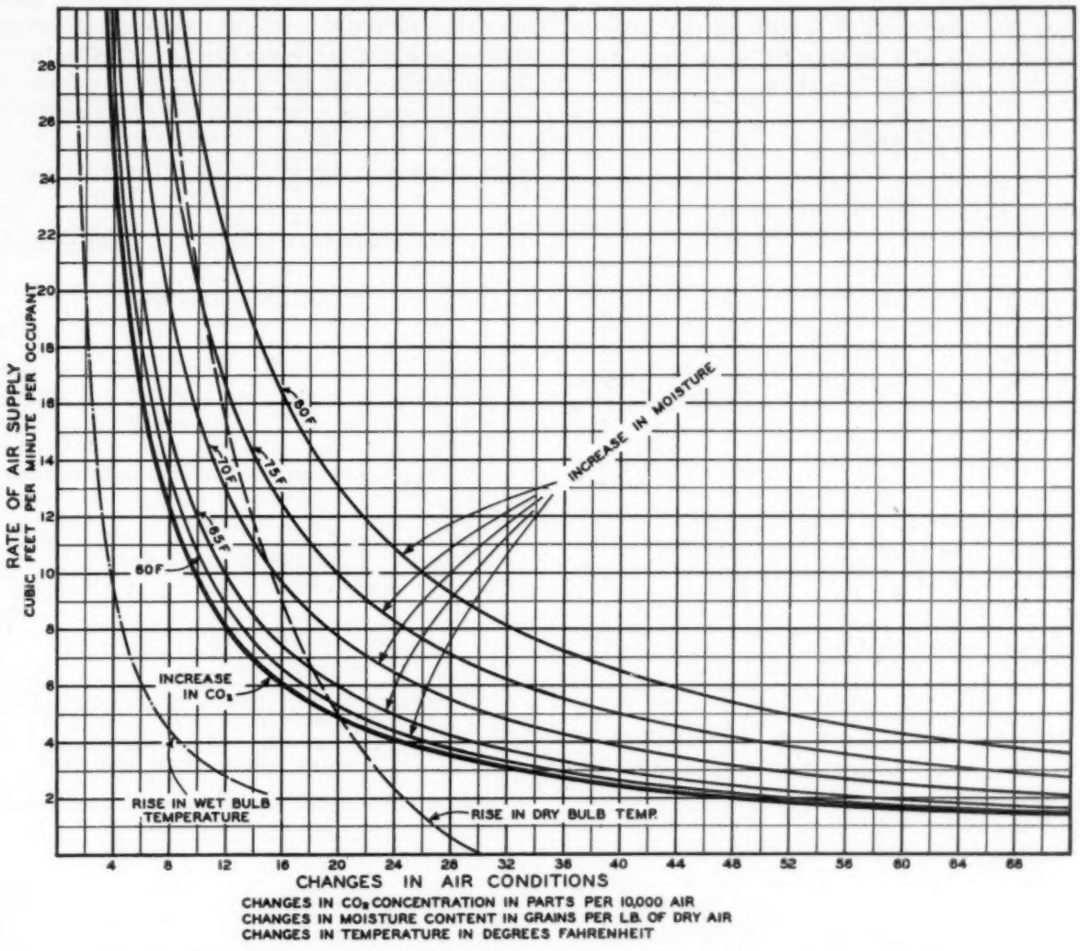
[2]Heat and Moisture Losses from Men at Work and Application to Air Conditioning Problems, by F. C. Houghten, W. W. Teague, W. E. Miller and W. P. Yant (Figs. 2 and 3). A. S. H. V. E. JOURNAL SECTION (*Heating, Piping and Air Conditioning*), June, 1931.

by him remain in the air. An average sized man, having a surface area of 19.5 sq ft as determined by the Du Bois chart[1, 3], is used throughout this paper.

As the rate of $CO_2$ dissipation remains the same for a wide range of normal temperatures only one curve results from plotting changes in $CO_2$ concentrations against changes in ventilation rates. Since moisture dissipation from the human body varies with dry-bulb temperature, a series of moisture curves is given for various temperatures so that the rate of ventilation for any temperature between 60 and 80 F can be obtained by interpolation. The curve for change in sensible heat is based upon an initial condition of 70 F. The use of dry-bulb temperature rise as an index of ventilation is precluded because, as verified by test, a large part of the heat is absorbed by the surrounding walls and furniture as soon as the temperature of the air rises. Of the two remaining changes, concentration of $CO_2$ and moisture content, assuming that neither is absorbed by walls or furniture, the one more easily determined should make the better index.

Ordinarily, increase in moisture content is measured by a change not only in wet-bulb temperature but also by a simultaneous change in dry-bulb temperature. Since it would be impossible to predetermine these two changes, a curve has been plotted on Fig. 1, *for comparison only*, showing relative changes in wet-bulb temperature when the dry-bulb temperature remains constant at 70 F and the moisture content of the air varies upward from 40 per cent relative humidity. Reading this wet-bulb curve in comparison with the $CO_2$ curve, it is seen that when the air change is approximately 10 cu ft per minute per occupant, a change in the rate of air supply of 1 cu ft per minute per occupant will result in a $CO_2$ change of 1.0 part in 10,000 and a wet-bulb temperature change of 0.4 deg, assuming a constant dry-bulb temperature of 70 F. For other rates of air change, approximately the same relation holds between change in wet-bulb temperature and change in $CO_2$ content. Hence, if a wet-bulb temperature change of 0.4 deg can be more easily determined than a $CO_2$ change of 1.0 part in 10,000, it is obvious that the moisture content method is the better measure of air change or air distribution, assuming of course that the moisture dissipated to the atmosphere is retained therein to the same extent as the $CO_2$.

Wet-bulb temperatures can easily be determined by




Change of $CO_2$ content applies to any atmospheric condition over a large temperature range. Change in moisture content is for any atmospheric condition having the dry-bulb temperature indicated. Change in wet-bulb and dry-bulb temperatures from initial condition of 70 F dry-bulb and 40% relative humidity. Volume of air supply corrected to 29.92 inches barometric pressure, 70 F dry-bulb, and 40% relative humidity.

**Fig. 1—Relation between change in air conditions and air supply per occupant**

[3]Du Bois, D. and E. F. (*Archives of Int. Med.*, 1916, Vol. 17, p. 865).

the use of ordinary thermometers to an accuracy of one-half of a degree; with the use of better thermometers, accurately read, wet-bulb temperatures can be determined to an accuracy of one-tenth of a degree. Compared with these simple readings, the determination of $CO_2$ content in the air is much more difficult, because it involves the collection of samples of air, the preserving of them while they are being transported to the laboratory, and the use of highly specialized apparatus, such as the Petterson-Palmquist analyser, which requires infinitely greater skill and manipulation than that needed in the taking of sling psychrometer readings. This reasoning would indicate that the moisture content of the air is a more convenient and usable measure of air change in a ventilated space than is its $CO_2$ content.

## Test Methods

In order to verify the above deductions and in order to determine the extent to which either the moisture or the $CO_2$ dissipated to the atmosphere by an occupant may be absorbed by surrounding objects, a number of tests were made in the psychrometric chambers of the Research Laboratory of the American Society of Heating and Ventilating Engineers at the United States Bureau of Mines Experiment Station, Pittsburgh, Pa. Fig. 2 is a sketch of the two rooms which are more fully described in a previous Laboratory report.[4] The temperature and moisture content of the air in the second chamber were held constant both during a test and for a considerable time before it by ventilating the room with a large volume of air at fixed temperature and dewpoint, supplied from the air conditioning equipment located in an adjoining room. The first chamber, in which the tests were made, was independently ventilated with air from the second chamber. When the conditions in both the first and second chamber had remained constant and equal to the conditions supplied by the air conditioning equipment for a sufficient length of time to insure equilibrium, the test was begun by admitting the subjects and seating them at rest uniformly over the floor area of the test chamber. It was assumed that any changes in the properties of the air in the test chamber during the test period resulted from occupancy. From eight to ten adult male subjects participated in the respective tests. Their rate of $CO_2$ production and heat and moisture dissipation was calculated from their body surface areas as given by the Du Bois Chart and the Laboratory data for the air conditions pertaining in the test room.

Difficulty was experienced in controlling the amount of ventilation in the first chamber to a predetermined quantity of air. By one method, air was moved from the second chamber to the first by building up a pressure in the second chamber, as a result of which air passed into the first chamber from which it was allowed to escape through a calibrated orifice into the corridors of the building. An attempt was made to measure the quantity of ventilation by these orifice readings, but it was found that exfiltration through the walls of the chamber, even with the small pressure differences maintained, amounted to more than the air flow through the orifice. Another method maintained equal pressures, as measured on a Wahlen gage, in both chambers and in the corridors and allowed no movement of air to or from the first chamber other than that through a two-foot square opening in the doorway between the first and second chambers, through which the air was allowed to circulate at will between the two as through an open window. This method gave uniform conditions throughout a test, but it did not give an accurate measure of the quantity of air used to ventilate the test room, and hence, while it gave a satisfactory comparison between the $CO_2$ and the moisture content methods of determining ventilation, it did not give an absolute check on either. The most successful test conditions were had by using a small blower to move air from the second chamber into the first through a calibrated orifice, and by controlling the size of the exit opening from the first chamber into the corridor of the building, so as to maintain a pressure of approximately 0.001 of an inch of water column in the first chamber over that in the corridor and in the second chamber. This method was used in most of the tests. The methods failing to give control are mentioned to show that large leakage losses usually result in ventilated space, in addition to the ventilation load supplied under control by the installed equipment.

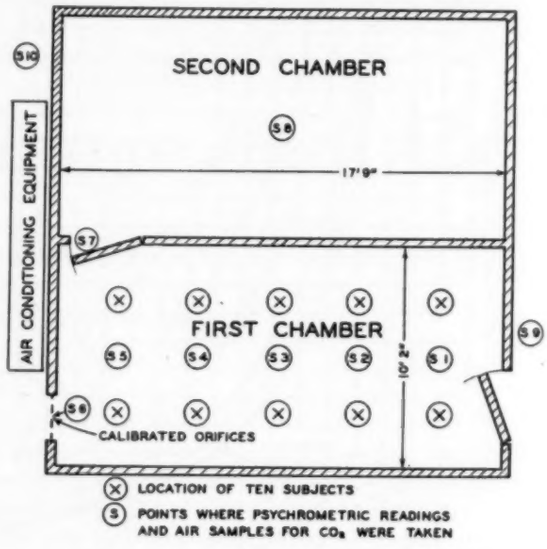



**Fig. 2—Psychrometric chambers used in ventilation study**

A number of tests were made, each with a different rate of ventilation as measured in cubic feet per minute per occupant of air corrected to 29.92 in. barometric pressure, 70 F dry-bulb, 40 per cent relative humidity. During the progress of each test samples of air for analysis for $CO_2$ were taken and readings of the sling psychrometer were made at various stations within the test room, in the second chamber, and in the corridors. To prevent contamination, the gas samples were held in clean, dry, mercury sealed bottles. To avoid discrepancies in temperatures, all wet-bulb and dry-bulb readings were taken on the same sling psychrometer. Each test was continued until constant conditions in the first chamber had been reached and maintained for a sufficient length of time to insure equilibrium. The average time

[4]Determining Lines of Equal Comfort, by F. C. Houghten and C. P. Yaglogiou. A. S. H. V. E. TRANSACTIONS, Vol. 29, 1923, pp. 163-175.

taken for each test was ninety minutes. From the increase in $CO_2$ concentration between the initial and final conditions as indicated by the analyses of the samples collected, the air change in cubic feet per minute per occupant was calculated from the following formula which applies after equilibrium has been reached:

$$R = \frac{\frac{C}{60} \times \frac{S}{19.5}}{P \times 10^{-4}}$$

*where:*

$R$ = ventilation rate in cubic feet per minute per occupant (standard conditions).

$C$ = $CO_2$ production rate, in cubic feet per hour per average sized man of 19.5 sq ft (standard conditions).

$S$ = area of average subject, in square feet.

$P$ = increase in $CO_2$ concentration, in parts per 10,000.

Similarly, the air change was calculated from sling psychrometer readings applied to the psychrometric chart as follows:

$$R = \frac{M \times \frac{S}{19.5}}{G \times w}$$

*where:*

$R$ = ventilation rate in cubic feet per minute per occupant (standard conditions).

$M$ = moisture production rate in grains per minute per average sized man of 19.5 sq ft (standard conditions).

$S$ = area of average subject, in square feet.

$G$ = increase in moisture content in grains per pound of dry air as actually determined from wet and dry-bulb readings and psychrometric chart.

$w$ = weight of air in pounds per cubic foot (standard conditions).

## Test Results

Air changes in a typical test as calculated from $CO_2$ and moisture increase at five respective sampling stations are plotted against time in Fig. 3. In this test, ten subjects occupied the first chamber, and the ventilation both inward and outward took place through an opening 10 in. by 29 in., located 8 in. above the floor in the doorway between the two chambers. Because this set-up did not permit measurement of the actual ventilation, the results could not be checked to a known air change, but they are of interest in indicating the uniformity of air distribution to the different stations throughout the room. While the volumetric capacity of the test room, 1450 cu ft, required considerable time for the establishment of equilibrium conditions, the curves show that equilibrium was very nearly reached 70 minutes after occupancy. This test was of interest in a number of respects. First, the results of the analyses of $CO_2$ and the determination of grains of moisture at the different stations indicate very satisfactory distribution of air throughout the different stations in the room in spite of the use of a type of ventilation which would be expected to give poor distribution. This air distribution was later checked by smoke tests which showed that convection currents in the neighborhood of each occupant, set up by heat dissipation from his body, mixed the air in the room. Second, the indicated air changes as calculated from $CO_2$ increases and from grains of moisture increases differed little. A slightly greater air change is indicated by the grains of moisture method in this particular test, but this relation was not uniformly substantiated in later ones. Third, the test shows a surprisingly high air change for the room, considering the small opening through which both the incoming and outgoing air had to pass, with no pressure difference or wind effect to cause circulation.

The curves, "air change calculated from dry-bulb temperature rise," shown in the upper part of Fig. 3 were obtained by calculating air change from differences in sensible heat as determined by dry-bulb temperature rises. These curves indicate ventilation rates about eight times as great as those found by calculations using $CO_2$ or moisture content, and are so irregular and inconsistent with the estimated ventilation in the room, that they show that sensible heat is not a satisfactory measure of air change. The rises in both wet and dry-bulb temperature resulting from occupancy are also plotted.

The results of $CO_2$ analysis and grains of moisture determination for all tests are plotted in Figs. 4 and 5, respectively, where the calculated ventilation in cubic feet per minute per occupant is plotted against the known ventilation in cubic feet per minute per occupant as measured when supplied by the ventilating system. The results obtained by both methods of calculation are higher than the measured air change. With the exception of one point, at an air change of 18.1 cu ft, the results of grains of moisture determinations are much more consistent and show less variation between individual points than do those of the determinations resulting from $CO_2$ analysis.

For comparison, Curve *B*, plotted in Fig. 4, is shown as a broken line on Fig. 5, and Curve *C*, plotted in Fig. 5, is shown as a broken line on Fig. 4. It may be seen that there is a close relation between the $CO_2$ and the moisture curves, and that they bear similar relationships to the measured ventilation curve.

The discrepancies between the diagonal curve *A* and curves *B* and *C* in Figs. 4 and 5 which show larger calculated air changes than those measured by the ventilating system may be accounted for in several possible ways: (1) the dilution effect of the air represented by the original volumetric capacity of the room over the ventilation rate during the test period; (2) the absorption of part of the $CO_2$ and water vapor dissipated to the atmosphere by the walls and other surfaces within the room; (3) possible error in the measurement of the air supplied; (4) unmeasured infiltration; (5) possible error in assumption that the rates of $CO_2$ production and moisture dissipation by the occupants are the same as those for the conditions of the tests reported in the earlier Laboratory studies.

*Dilution.* The effect of the volumetric capacity of the room on the concentration of $CO_2$ and water vapor in it at the end of the test period may be calculated by the dilution formula:[5]

$$Q = \frac{V_r}{V_v} V_{ss} \left(1 - e^{-\frac{V_v}{V_r} t}\right) + Q_o e^{-\frac{V_v}{V_r} t}$$

*where:*

$Q$ = volume in cubic feet of carbon dioxide or water vapor in the room at any time, $t$.

$t$ = elapsed time in minutes.

$V_r$ = volume of room in cubic feet.

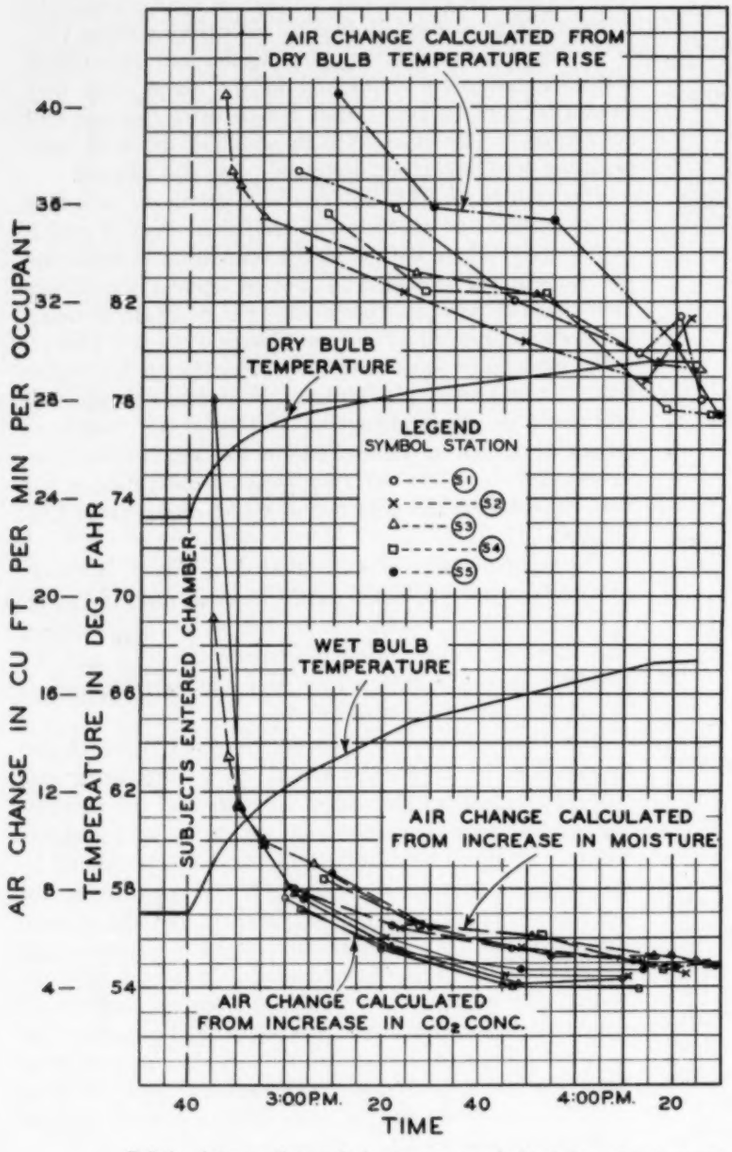
$V_v$ = volume of air supplied in cubic feet per minute.

[5]Carbon Monoxide Distribution in Relation to the Ventilation of an Underground Ramp Garage, by F. C. Houghten and Paul McDermott. A. S. H. V. E. Journal Section, *Heating, Piping and Air Conditioning*, August, 1932, pp. 559-72

$V_{co_2}$ = volume, in cubic feet, of carbon dioxide or water vapor added to the room per minute.
$Q_o$ = volume in cubic feet of carbon dioxide or water vapor in the room at the beginning of the time considered, or when $t = 0$
$e$ = base of the Naperian system of logarithms, 2.71828.

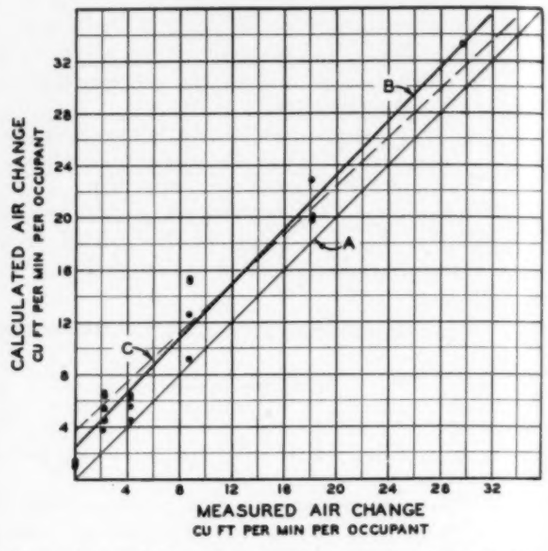
Except for very low air change rates, application of the above formula shows that there was little error introduced by dilution in the test chamber due to the original volume of air in the room. When the test chamber was occupied for ninety minutes by ten subjects and was ventilated at a constant rate of 10 cu ft per minute per occupant, the error introduced in using equilibrium conditions in the calculations amounted to less than one per cent.

*Absorption.* No satisfactory measure can be made of the effect of absorption of water vapor and $CO_2$ from the air by walls and other surfaces. It is generally assumed that under changing temperature and humidity conditions such surfaces have a high affinity for water vapor but not for other gases. There are no data available, however, to prove that water vapor in the amounts in which it is contained in the atmosphere under the conditions of these tests should act differently than $CO_2$ or any other gas. In fact, one may assume that with changes in temperature and $CO_2$ concentration, plaster and other masonry material, largely made up of carbonates, might absorb or expel relatively more $CO_2$ than water vapor. It would seem expedient to accept the few data presented in Figs. 4 and 5 as evidence that absorption is not a considerable factor in either method. It



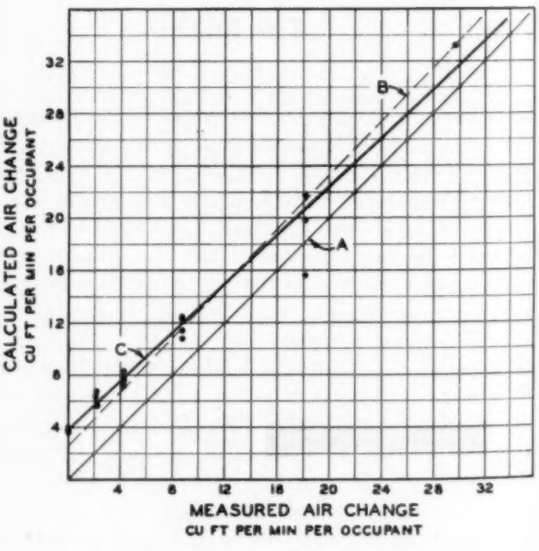

Relation between time and air changes as calculated from $CO_2$ increase, moisture increase and dry bulb temperature rise. Also the relation between time and dry-bulb and wet-bulb temperatures of the test room.

**Fig. 3—Data from typical test**




Data points and Curve *B* from $CO_2$ analysis. Curve *C* from moisture determinations, Fig. 5. Curve *A*, measured air change.

**Fig. 4—Relation between measured air change and air change calculated from air conditions**




Data points and Curve *C* from moisture determinations. Curve *B* from $CO_2$ analysis, Fig. 4. Curve *A*, measured air change.

**Fig. 5—Relation between measured air change and air change calculated from air conditions**

must, however, be borne in mind that when glass or other surfaces in a room are cooled below the dewpoint of the atmosphere so that condensation takes place on them, the grains of moisture determination method could not be used to measure air distribution. Also, if the amount of ventilation in a room is so low that occupants cause the air to approach saturation, the water vapor method could not be used with confidence. Further, in cases where the air in a room is humidified, care must be taken to determine the moisture content at the source of the air with which the room is ventilated. This would not be the moisture content of the air outside, but that of the air entering the room from the conditioning system.

*Error in Assumptions.* Erroneous assumption of the rates of $CO_2$ production and moisture dissipation by the test subjects may easily be a factor affecting the discrepancy between the diagonal Curve *A* and Curves *B* and *C* in Figs. 4 and 5, by reason of a difference of degree of activity of the subjects in the original Laboratory studies of heat and moisture dissipation and of the subjects in the present tests. An attempt was made to keep the subjects in both studies seated at rest as they would be in a school or audience hall. However, the short duration of the present series of tests compared with the longer duration of the series in the earlier study resulted in less effective discipline of the subjects in the present study. It should be noted that increased physical activity of the subjects increased the rates of dissipation of both $CO_2$ and moisture by approximately the same percentages, and that such increase in activity would help account for the discrepancy between Curve *A* and Curves *B* and *C*.

The increase in $CO_2$ or grains of moisture content of the air in a ventilated space may be used for two different purposes in a ventilation survey. First and more usually, it may be used as a measure of uniform air distribution throughout the room; second, it may be used as a measure of the total volume of air being supplied to the room. If used for the first purpose, errors in rate of $CO_2$ or rate of moisture dissipation will have little effect, for the interest lies in the variation of distribution of air through the room. If, however, either method is used to determine the total quantity of air being supplied to the room, the accuracy of the result will depend on the accuracy of the assumption of rate of dissipation of $CO_2$ or water vapor. The two Laboratory papers[1, 2] dealing with heat and moisture losses from the human body and giving results for a person seated at rest as in an audience hall and for a person working at diverse fixed rates, and data gleaned from reports of other investigators on variation of metabolism with variation in activity, furnish bases for a fairly satisfactory assumption of rates of $CO_2$ and moisture dissipation from occupants in a ventilated space.

*Odors.* While the study was not designed as a comprehensive investigation of the relation of odors to air change, it did offer an opportunity for a few observations which may be of interest. For all tests made with air changes greater than 10 cu ft per minute per occupant the air in the room seemed free from odors or depressing effects. For air changes of 10 cu ft per minute per occupant odors were noticeable to a person entering the room from the outside atmosphere, and the general condition of the room air seemed depressing and stuffy. However, in all cases where the air change was 10 cu ft or less the temperature was uncomfortably high. The tests were usually started at approximately 70 F dry-bulb, but the heat dissipation from the subjects made it rise about 6 deg when the air change was 10 cu ft per minute per occupant, and more when the air change was less than 10 cu ft. Since it is generally accepted that odors are closely related to temperature, increasing rapidly with its rise above 70 F, the odor effects noticed with air changes of 10 cu ft and less may have resulted from the high temperatures rather than from the small air changes. For air changes of 5 cu ft per minute per occupant or less, the condition in the test room became distinctly obnoxious and depressing to a person entering from the outside. With ten subjects, the test room had a capacity per occupant of 145 cu ft which made it somewhat more crowded than is accepted as good practice in schools.

*Air Motion in Relation to Air Distribution.* The inconsistency shown on Figs. 4 and 5 between the points determined from $CO_2$ analysis and those obtained from the moisture content determinations may be caused by differences in physical functions and technical methods. The human body dissipates $CO_2$ to the atmosphere by the exhaled breath, which is ejected with concentrations of $CO_2$ ranging from 200 to 500 parts in 10,000 parts of air. Hence, large variations in concentrations of $CO_2$ may be found at points in the atmosphere two or three feet from the occupant for small periods of time, even with what might otherwise be considered good air distribution. Since the samples of $CO_2$ are customarily taken by hand, it is reasonable to suppose that even with the utmost care, the observer's own breath may sometimes contaminate them.

At a dry-bulb temperature of 70 F, about 35 per cent of the moisture dissipated to the atmosphere by the human body comes from the respiratory tract. The remaining 65 per cent comes from the body surface. Thus, since approximately one-third of the possible water vapor dissipation comes from the breath, there is less likelihood than with $CO_2$ of having large concentrations of water vapor at points in the atmosphere a few feet from the occupant in a well ventilated room. Further, the very nature of the method of making a sling psychrometer reading tends to break up any concentrated pockets of water vapor and to give an integrated reading of the moisture content of a circle from 30 to 40 in. in diameter about 2 ft in front of the observer.

It is probable that these differences in a large measure account for the fact that $CO_2$ points in Fig. 4 are less consistent than the grains of moisture points in Fig. 5. It seems, however, that the difference in measurement and dissipation of moisture should not affect the true purpose of the determination. A room in which air is well distributed and where air motion is sufficient for good ventilation might conceivably give samples of air in which a breath of high concentration $CO_2$ has floated. The grains of moisture determination, because obtained by an integrated reading over a fairly large area in any part of a room, would seem to be representative of the air supply to that part of the room.

Consideration of this question suggests that air motion throughout a room might be a better index of air distribution than either $CO_2$ or grains of moisture. In none of the tests here recorded, even with highly localized

points of air admission and exit, was there any consistent variation shown in the distribution of $CO_2$ or water vapor as between the end of the room where the air was supplied and removed and its opposite end. However, it should be borne in mind that this room was small. Convection currents seemed to be quite effective in mixing the air. Perhaps the distribution of air to each particular corner or section of a room by the ventilating system is not so much needed in a well ventilated space as is sufficient air motion throughout a room to break up stagnant air pockets next to occupants. It is accepted in ventilating practice that for good ventilation, the air in all parts of a room should have a velocity of from 20 to 50 ft per minute as measured by the Kata thermometer. If air could be supplied to every section of a room without air motion, the ventilation would still be unsatisfactory, but if such air velocities do exist locally throughout a room, good mixing or uniform distribution will be had whatever the location of the supply and exhaust. Hence, the question arises as to whether or not air velocities as measured by the Kata thermometer throughout a room might not give better assurance of mixing and air distribution than is given by either $CO_2$ or water vapor. It would seem that this question could bear further consideration. Obviously, air motion cannot be used as a measure of the rate of air supply.

### Application

The curves presented in Fig. 1 may be used directly for solving air change and air distribution problems. For example, the characteristics of air supplied to ventilate a room are:

| | |
|---|---|
| $CO_2$ content | 4 parts per 10,000 |
| wet-bulb | 55.0 F |
| dry-bulb | 68.0 F |
| moisture content (from psychrometric chart) | 43.0 grains per pound of dry air |

and the characteristics of the air in the ventilated, occupied room under equilibrium conditions are:

| | |
|---|---|
| $CO_2$ content | 10 parts per 10,000 |
| wet-bulb | 59.1 F |
| dry-bulb | 72.0 F |
| moisture content (from psychrometric chart) | 53.3 grains per pound of dry air |

The increase in $CO_2$ is 6 parts in 10,000 which from the $CO_2$ curve in Fig. 1 gives an air change of 16.5 cu ft per minute per occupant. The increase in grains of moisture is 10.3 grains, which from an interpolation of the moisture curves in Fig. 1, shows that at a temperature of 72.0 F, the air change is also 16.5 cu ft per minute per occupant.

### Summary and Conclusion

Calculations determined from $CO_2$ and grains of moisture increases indicate a somewhat higher air change than that supplied by the ventilating system. The difference may result from absorption of $CO_2$ and water vapor by walls and other surfaces or from erroneous assumptions of the rates of $CO_2$ and moisture dissipation as taken from the earlier Laboratory studies. However, the discrepancies noted are not sufficient to seriously affect the use of either method as a measure of air change or air distribution.

Greater consistency is shown among individual determinations of air change made by the moisture content method than among determinations made by the $CO_2$ method.

Measurement of air change in a room by sling psychrometer can be made more quickly and with much greater ease than by the lengthy and complicated $CO_2$ method. Since the accuracy of the wet and dry-bulb method is as great or greater than that obtained through the use of $CO_2$, it is recommended as the more desirable method for making ventilation determinations.

Observations made in a room with controlled and measured rates of air change indicate pronounced odors for air changes less than 10 cu ft per minute per occupant when the dry-bulb temperature was above 75 F.

The tests and the deductions suggest an air motion of from 20 to 50 ft per minute, determined by the Kata thermometer, as a possible index of satisfactory air distribution.

## Method of Choosing Location of, Financing and Conducting Meetings of the Society

*Resolved:* That inasmuch as the Annual and Semi-Annual Meetings of the Society come under the jurisdiction of the Council, the following rules governing the handling of such meetings be adopted by the Council and published in the JOURNAL of the Society at least twice during every year, preferably just prior to each meeting:

1—The Council will select the city in which the Annual or Semi-Annual Meeting is to be held, giving due consideration to the invitations received from Chapters or members as well as to the advisability of so distributing those meetings as to make them of the greatest advantage to the general membership, and to reduce as far as possible the expense of members attending.

2—That an appropriation be made to cover the entertainment or local expenses, incurred in connection with the meeting not exceeding $500.00, the regular meeting expense to be taken care of by the General Fund of the Society in the regular way.

3—That no registration fee or compulsory obligations of any nature be imposed on members or guests.

4—That the purchase of tickets for banquets or for any other form of entertainment that may be provided be entirely voluntary.

5—That the grouping of features and the same of tickets for group features be discouraged.

6—That the raising of Funds from manufacturers of heating apparatus be discouraged.

7—That the display of samples, or of literature, advertising the product of any manufacturer in any way, shape or form, be not permitted at the booths, registration desk, or in or about the meetings.

8—That the distribution of trade papers be entirely at the discretion of the committee in charge.

9—That the local Chapter, or local members, be empowered to form a General Committee with such sub-committees as may be required to handle the details of transportation, hotel accommodations, entertainment, finance, etc., and that this General Committee be requested to confer frequently with the Council, through the Secretary of the Society, and to make frequent reports on progress in connection with the various matters being handled by them.

10—That the arrangements of elaborate and costly entertainment features be discouraged.

*Adopted at Council Meeting, January 29, 1926.*

**Approaching Detroit and the Ambassador Bridge to Canada**

# Welcome to Detroit!

A DELIGHTFUL program has been prepared for the Semi-Annual Meeting 1933 by the Michigan Chapter Committees working under the direction of L. L. McConachie, General Chairman of the Committee on Arrangements. Headquarters have been established at the Hotel Statler and a cordial welcome awaits every member, who attends this meeting, which will be held June 22-24, with technical sessions each morning and the afternoons and evenings reserved for entertainment that will appeal to every taste.

Eight committees have been working steadily for several weeks to make the program a success and the chairmen of the sub-committees who form the Arrangements Committee are introduced at this time. Each Michigan Chapter member will have a distinctive badge with a red, white and blue ribbon, so that they may be easily identified as hosts.

The work of the Reception Committee, in charge of R. K. Milward, will commence on the day before the sessions formally open. Early arrivals will attend various committee meetings and a dinner meeting of the Council on Wednesday, June 21 at 6:30 p. m. Detroit has *Eastern Standard Time* and all events are scheduled accordingly.

Registration will be directed by E. E. Dubry commencing Thursday morning at 8:30 a. m. on the ballroom floor of the Hotel Statler, where members and guests will be provided with badges, programs and advance copies of meeting papers and reports.

A special program of entertainment has been prepared for the ladies and W. G. Boales, Frank Feely and a group of hostesses are cooperating, so that everyone will have an enjoyable motor trip and luncheon on Thursday afternoon and a pleasant trip to the Detroit Art Gallery on Friday afternoon.

In addition, of course, there will be a buffet supper and dance at Meadowbrook Country Club, Thursday night, and the Annual Banquet at the Grosse Pointe Yacht Club on Friday evening.

While the ladies are being entertained, the men will participate in a golf tournament, Thursday, at the Meadowbrook Country Club and on Friday they will play for the Research Cup on the Lochmoor Country Club course. For those who do not play golf, Tom Brown and his committee are prepared to provide entertainment in the form of tennis, quoits, cards or visits to several of the well known industrial plants.

The banquet Friday evening will be informal and the program for this affair at the Grosse Pointe Yacht Club is being directed by R. F. Connell. Transportation is in the hands of J. L. Fuller; finances are being cared for by E. H. Clark; and the publicity is being directed by G. D. Winans.

While a good time is promised to everyone, there are important matters to be considered at the technical sessions on Thursday, Friday and Saturday mornings. These will be held at the Hotel Statler and the work of two code committees, which has been under way for several years, will be brought before the members for approval.

The list of papers is an impressive one and several result from the work of the Society's Research Laboratory and cooperating institutions.

A paper of outstanding importance is, The Application of the Eupatheoscope for Measuring the Performance of Direct Radiators and Convectors in Terms of Equivalent Temperature, by A. C. Willard, A. P. Kratz and M. K. Fahnestock, the investigations having been conducted at the University of Illinois. The third report on the Measurement of Air Flow through Grilles will be given by Prof. L. E. Davies and two very practical contributions are those on A Pipe Sizer by L. A. Cherry and Studies of Temperature Gradients by Prof. G. L. Larson, D. W. Nelson and O. C. Cromer. Samuel R. Lewis, consulting engineer of Chicago, has contributed a paper on the Testing and Rating of Air Cleaning Devices and three years study of Thermal Conductivities of Lumber will be outlined by Prof. F. B. Rowley. The Effects of Ionized Air will be discussed by Prof. C. P. Yaglou and two contributions from the Society's Research Laboratory, directed by F. C. Houghten, give important data on Indices of Air Change and the Carbon Monoxide Distribution in a Garage.

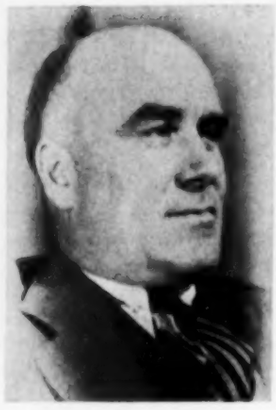
These subjects are of widespread interest and should start

**R. K. Milward**
*Reception*

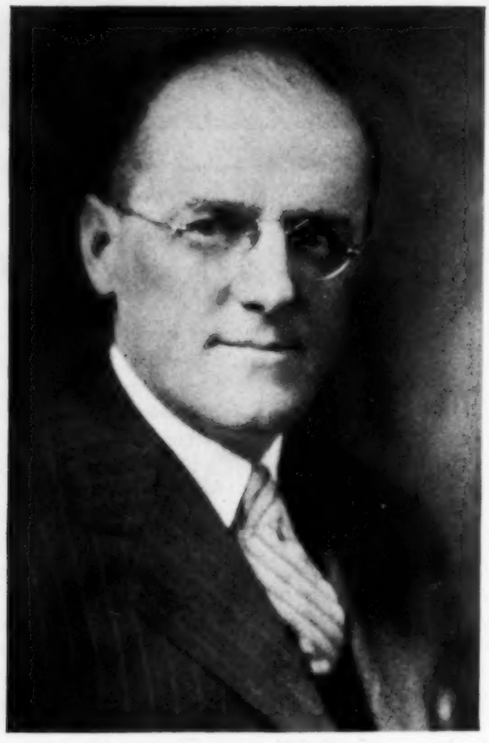
**W. G. Boales**
*Ladies*

**E. H. Clark**
*Finance*

**J. L. Fuller**
*Transportation*

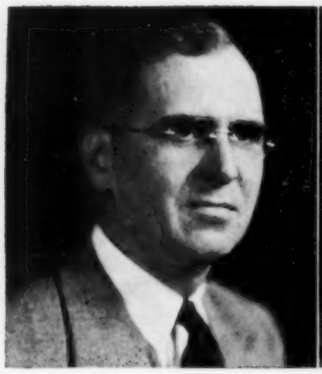


**L. L. McConachie**
*General Chairman*



**W. T. Jones**
*Boston, Mass.*
*President of the Society*

**H. E. Paetz**
*Vice-Chairman*



**E. E. Dubry**
*Registration*

**R. F. Connell**
*Banquet*

**Tom Brown**
*Entertainment*

**G. D. Winans**
*Publicity*

interesting and worthwhile discussions at the three sessions.

The cost of attending the meeting is an important consideration and the Michigan Chapter Committee has devised a program that will bring a large amount of enjoyment for very moderate cost. Banquet tickets and golf fees are lower than those in effect on any previous occasion.

The railroads have authorized reduced rates for the round trip of *fare and one-third* and tickets can be secured to continue to Chicago for the Century of Progress during Engineers' Week at special rates granted for this period.

Detroit is readily accessible and a cordial invitation from the Michigan Chapter has been mailed to all members. Hotel reservation cards, railroad certificates and other information will be sent to members on June 1.

This year A. S. H. V. E. members have an unusual opportunity to spend three delightful days in Detroit at the Semi-Annual Meeting, June 22-24, and attend Engineers' Week at the Century of Progress, Chicago, June 25-30. It is the opportunity that comes once in a lifetime!

## PROGRAM SEMI-ANNUAL MEETING 1933

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

Hotel Statler, June 22-24, Detroit, Mich.

**Wednesday, June 21**
(Eastern Standard Time)

6:30 p. m. Dinner and Council Meeting

**Thursday, June 22**
(Eastern Standard Time)

8:30 a. m. Registration (Ballroom Floor—Hotel Statler)

9:30 a. m. Greeting by President Michigan Chapter and President Western Michigan Chapter

Response by Pres. W. T. Jones

Temperature Gradient Observations in a Large Heated Space by G. L. Larson, D. W. Nelson and O. C. Cromer

Indices of Air Change and Air Distribution by F. C. Houghten and J. L. Blackshaw

Testing and Rating of Air Cleaning Devices Used for General Ventilation Work by S. R. Lewis

Report of Committee on Atmospheric Dust and Air Cleaning Devices, H. C. Murphy, Chairman

11:45 a. m. Ladies Motor Trip and Luncheon—Bus leaves Hotel Statler—Luncheon at Dearborn Inn followed by tour of Greenfield Village—Ladies will leave at 5:00 p. m. for Meadowbrook Country Club

1:00 p. m. Meeting of Membership and Chapter Relations Committees, E. K. Campbell, Chairman

1:00 p. m. Golf Tournament—Meadowbrook Country Club

7:30 p. m. Buffet Supper, Music and Dancing—Meadowbrook Country Club

**Friday, June 23**
(Eastern Standard Time)

9:00 a. m. Meeting Nominating Committee.

9:00 a. m. Meeting Committee on Ventilation Standards, W. H. Driscoll, Chairman

9:30 a. m. A Pipe Sizer for Determining the Sizes of Pipes and of Restricting Orifices in a Hot Water Heating System, by L. A. Cherry

The Application of the Eupatheoscope for Measuring the Performance of Direct Radiators and Convectors in Terms of Equivalent Temperature by A. C. Willard, A. P. Kratz and M. K. Fahnestock

Tests of Convectors in a Warm Wall Testing Booth (Part II) by A. P. Kratz, M. K. Fahnestock and E. L. Broderick

Report of Committee on Code for Testing and Rating Convection Heaters (Hot Water Section), R. N. Trane, Chairman

12:30 p. m. Ladies Luncheon (Hotel Statler)

1:00 p.m. Conference—Committee on Nomenclature, S. R. Lewis, Chairman

1:00 p. m. Golf Tournament — (Research Cup) — Lochmoor Country Club

Visit to Industrial Plants

2:00 p. m. Visit to Detroit Art Institute to view famous paintings and Rivera's murals

5:30 p.m. Buses leave Hotel Statler for Grosse Pointe Yacht Club—Touring Belle Isle en route

7:45 p. m. Semi-Annual Banquet and Dance (Informal) at Grosse Pointe Yacht Club

**Saturday, June 24**
(Eastern Standard Time)

9:30 a. m. The Heat Conductivity of Wood at Climatic Temperature Differences by F. B. Rowley

Physiologic Changes during Exposure to Ionized Air by C. P. Yaglou, A. D. Brandt and L. C. Benjamin

Measurement of Air Flow through Grilles by L. E. Davies

Carbon Monoxide Distribution in Relation to the Heating and Ventilation of a One-Floor Garage by F. C. Houghten and Paul McDermott

1:00 p. m. Luncheon and inspection of air conditioning exhibit at American Blower Corp. plant

## COMMITTEE ON ARRANGEMENTS

*General Chairman*—L. L. McConachie
*Vice-Chairman*—H. E. Paetz
*Representative Western Michigan Chapter*—J. F. Johnston, Jr.

*Finance Committee:* E. H. Clark, *Chairman*, J. D. Cantwell and M. F. Mattingly.

*Reception Committee:* R. K. Milward, *Chairman*, W. G. Boales, R. F. Connell, E. E. Dubry, L. L. McConachie, W. A. Rowe, K. L. Ziesse and all hostesses.

*Registration Committee:* E. E. Dubry, *Chairman*, E. H. Clark, S. S. Sanford, J. W. Snyder and G. H. Tuttle.

*Transportation Committee:* J. L. Fuller, *Chairman*, and H. F. Reid.

*Entertainment Committee:* Tom Brown, *Chairman*, W. F. Arnoldy, E. Anderson, Lyman Phillips, E. D. Purdy and Wm. Watson.

*Banquet Committee:* R. F. Connell, *Chairman*, Harry Christenson, E. H. Clark, H. A. Hamlin, M. B. Shea and A. C. Wallich.

*Publicity Committee:* G. D. Winans, *Chairman*, J. S. Kilner and L. L. McConachie.

*Ladies Committee:* W. G. Boales, *Chairman*, F. J. Feely, *Vice-Chairman*, Mrs. W. G. Boales, Mrs. Tom Brown, Mrs. E. H. Clark, Mrs. R. F. Connell, Mrs. S. H. Downs, Mrs. E. E. Dubry, Mrs. F. G. Feely, Mrs. J. L. Fuller, Mrs. L. L McConachie, Mrs. J. F. McIntire, Mrs. R. K. Milward, Mrs. H. E. Paetz, Mrs. J. W. Snyder, Mrs. R. L. Spitzley, Mrs. A. C. Wallich and Mrs. G. D. Winans.

# Local Chapter Reports

## Cincinnati

*April* 11, 1933. The wide interest in Southern Ohio in School Room Ventilation and in A. J. Nesbitt (giving the Program Committee all due credit for advertising their meetings) was evidenced when some 20 engineers put in an appearance for a 6:00 o'clock dinner at which Mr. Nesbitt was guest of-honor. Guests included a group of visitors from Columbus: E. W. Brill, H. Erret, S. Lambert, Ed. Babbett, Sr., Ed. Babbett, Jr., Arthur Thingelstat, M. Hamilton, H. R. Allonier, A. Wollerman and Ed. S. Bigelow. Having shown full appreciation for a Gibson Dinner reminiscent of the Annual Meeting and companioned by Cincinnati's own brew, the meeting adjourned to the Engineer's Club, says the report of I. B. Helburn.

At 8:30, with some 60 engineers present, the meeting got under way with a triple play, Kitchell to Helburn to Nesbitt, handling the welcome, the introduction, and the address which was styled A Logical Determination of the Volume of Air to be Circulated in School Room Ventilation.

The address was premised on the discard of the old ventilating requirements expressed in terms of carbon dioxide, on the thought that class-room ventilation produces a problem of removing heat rather than adding heat, and on two factors determined by special investigations; the two factors being the sensible heat given up by a 15-year-old student; a value of 240 Btu, and the additional indication that circulated air should have a maximum temperature depression of 10 deg below room temperature, in order to avoid drafts.

With the basis for discussion developed, the 10 deg air-stream depression set up, it was developed that some 27½ cfm per occupant became a correct value, when all sources of heat-to-be-removed were considered, including the animal or body heat, light bulb and other similar sources, and the extremely important sun effect.

Supporting the theory and explaining the methods of investigation, a series of slides were shown indicating the test room, test equipment, and location of instruments at various positions and levels. Careful note was made of exhaust vents, and of correct mixture of room and out-door air, at various student loads for the test room and at various times of the day. Readings, findings, and general observations were tabulated on master charts and curves with a summation of the new volume determination as follows: Based on heat removal, 27½ cfm per high-school student, circulated at a temperature not more than 10 deg below room temperature will prevent over-heating without producing drafts, and that using these values in a system in which automatic control of room and air-stream temperature is essential the maximum variation in temperature throughout the occupied area will not be greater than 2 deg. Beyond the correctness of such a method for health and comfort, the resulting economy was duly stressed, remembering throughout the paper that volume of air for ventilation was the prime consideration.

At the conclusion of the address an extended discussion took place. Cincinnati's outstanding school consultant, Wm. E. Bodenstein, very kindly drew on his experience and records to lead the discussion, which was given added impetus by Messrs. Royer, Ehlers, Babbett, Rooks and Wollerman. Mr. Nesbitt very graciously answered all questions and explained points of particular interest and controversy.

The Chapter felt indebted to him and Mr. Kitchell closed the meeting by an expression of sincere appreciation.

*March* 14, 1933. M. A. Smith had dinner informally with E. B. Royer and several other members of the local Chapter, who were anxious to establish personal contact with the speaker of the evening before he had "delivered" and could be publicly "stoned" or "acclaimed."

The address proved to be extremely interesting to the 40 engineers who heard Mr. Smith cover Architectural Acoustics and Their Particular Relation to Heating and Ventilating. The talk was divided in two general sections: first, that section of acoustics or the science of sound which pertains to the behavior of sound in buildings; and second, investigation of general sound insulation and isolation.

Mr. Smith's address was prefaced with a very gracious tribute to Prof. W. C. Sabine, of Harvard University, who first formulated an expression for the reverberation time in a room. The first section of the paper then moved pleasingly through the nature of sound, its usual creation, pitch variance, amplitude, and constant speed characteristic, followed by a description of difference between pure tone and tones we ordinarily hear with general statement as to noise and other sounds.

With the fundamentals carefully taken care of, the members were advised of the sound control possibilities architecturally, including the application of sound absorbing materials to correct hearing difficulties in auditoriums, business offices, etc. Particular reference was made to very exacting work that has been accomplished in broadcasting studios, and to the fact that this and similar work is accomplished in a manner that lends to the architectural scheme or effect in design and in color.

The second section of the talk concentrated on isolation of heating and ventilating equipment noises and was effectively pointed by reference to treatment of installations of various standard trade items. Instructive slides were presented and the discussion centered on control of air noise, vibratory effects, mechanical equipment mountings, etc. Of general interest among the slides displayed was a unique set depicting a plaster church model and showing photographs of sound waves and their reflection.

Committeeman H. N. Kitchell, in charge of the meeting, expressed the appreciation of the local chapter for an address and appended discussion which were voted a place high on the chapter's list of interesting and instructive papers.

## Cleveland

*April* 14, 1933. The meeting of the Cleveland Chapter was called to order by Pres. R. G. Davis at 8:00 p. m. in the Chapter Rooms of the *Cleveland Engineering Society* with an attendance of 20 members and guests.

The minutes of the previous meeting were read by Secy. F. A. Kitchen and approved. W. E. Stark of the Membership Committee reported that a new member had been secured and the resignations of Messrs. Kammerer and Olson were received reluctantly.

President Davis requested that the treasurer's and secretary's reports be made at the next meeting.

T. A. Weager, C. F. Eveleth and W. E. Stark were appointed to act on the Nominating Committee and select candidates for officers for the ensuing year.

The chairman of the Program Committee, J. C. Miles, then took charge of the meeting and introduced the guest of the evening, W. T. Jones, Boston, President of the A. S. H. V. E.

Mr. Jones discussed the present activities of the Society, covering its program for research, membership and finance. His talk to the Cleveland Chapter resulted in an enthusiastic response from those present.

After general discussion by Mr. Jones in reply to questions from the members, a motion of appreciation and thanks was presented by Mr. Eveleth before the meeting adjourned at 10:00 p. m.

## Ontario

*May* 2, 1933. The annual meeting of the Ontario Chapter was held at the Parkdale Canoe Club at 6:00 p. m., when following a delightful dinner, the regular business was transacted.

Reports of various committees were received, including the treasurer's report, which presented a very favorable financial statement.

H. H. Angus made a motion that the Chapter have a golf meet during the latter part of May and arrangements will be made for this outing.

The following members were elected to hold office for the coming year:

*President*—W. P. Boddington.

*Vice-President*—W. R. Blackhall.

*Secretary-Treasurer*—H. R. Roth.

*Board of Governors*—M. W. Shears, J. S. Paterson and Thomas McDonald.

Pres. J. S. Wood turned the chair over to the incoming president, Mr. Boddington, who gave a short address. Later the meeting adjourned to bowling alleys, billiard and card rooms, where a very pleasant evening was spent.

## St. Louis

*May* 3, 1933. The May meeting of the St. Louis Chapter was preceded by a Buffet Dutch Lunch served in the Rathskeller of the home of the *Heating and Piping Contractors St. Louis Association.*

The assembly was called to order by Pres. C. A. Pickett and the minutes of the previous meeting were read and approved by Secy. C. R. Davis.

J. W. Cooper, chairman of the Entertainment Committee, reported that a golf, bridge and dinner dance party would be held at the Norwood Hills Country Club early in June and that announcements would be sent out in the near future.

The chairman of the Membership Committee, Paul Sodemann, read the application of James Barry, Jr., which was approved.

The meeting was then turned over to L. W. Moon, chairman of the Program Committee, who introduced G. D. Kingsland, of Minneapolis, Minn. Mr. Kingsland presented a paper pertaining to the development of self-contained thermostatic radiator supply valves, and his comments were augmented by stereopticon slides, showing laboratory test rooms and temperature charts.

The meeting was greatly enjoyed by the members and guests present.

## Western New York

*May* 8, 1933. The May Meeting of the Western New York Chapter, held as usual at Gandy's, marked the last technical gathering of the season and the attendance of approximately 25 members and guests at dinner and 45 at the meeting was very gratifying.

It was decided to abandon the customary June Dinner Dance at the Auto Club and the Entertainment Committee was instructed to look into the feasibility of having a Joint Golfing Party with the *Western New York Trade Golf Association.*

The speaker of the evening was C. A. Bulkeley, New York, who was fittingly introduced by the chairman of the Program Committee, M. C. Beman. Mr. Bulkeley, speaking on Air Cooling by the Surface Method, thoroughly covered the various phases of accomplishing the cooling of air by means of coils and extended surfaces containing cooled water or refrigerants. The speaker's treatment of the elemental definitions and clear presentation of this phase of cooling gave evidence of his long and varied experience in this field. Interesting slides provided further data and a rising vote of thanks was given Mr. Bulkeley for a most profitable evening.

## Members of Three Chapters Meet at La Crosse

*April* 25, 1933. A most enjoyable meeting was held at La Crosse, Wis., when 65 members and guests from the Illinois, Minnesota and Wisconsin Chapters gathered together for a day of education, good fellowship and social enjoyment.

The program started at 10:30 a. m. with an inspection trip through plants and laboratories of the Trane Co.

A splendid luncheon at the La Crosse Country Club including recently legalized trimmings put the group in fine fettle for the afternoon golf tournament. All signs of depression vanished when the meeting was flooded with millions in scrip in the form of Btu money, said scrip being secured by deposits with the treasurer in the rate of 50 cents in silver for each 1,000 Btu greenback.

Such inflation quickly turned the golf tournament into a hotly-contested game of skill and those whose confidence in the length of their drives, number of putts or what have you was matched with equal ardor by those who doubted such abilities existed.

Dinner was served at the Hotel Stoddard at 7:00 p. m. at the conclusion of which the following program was held:

Address of Welcome. Reuben N. Trane.
The Society, Past, Present and Future. Prof. F. B. Rowley, Past President, A. S. H. V. E.
Society Research Accomplishments. Prof. G. L. Larson, Chairman, Committee on Research.
The Thermodynamics of the Human Body. Dr. Plummer, Mayo Clinic.
Refrigeration Today. Reuben N. Trane.

These talks were very instructive as well as entertaining and were enjoyed by all present.

During the evening, Neil Adams, Toastmaster and Chairman of the meeting, called upon John Hale of Chicago and he responded with an interesting review of his connection with the Society, having been President of the A. S. H. V. E. in 1913 and a member for 31 years.

At the conclusion of the program, the real stag party started and it lasted "from then 'till then." Millions of B.t.u. greenbacks changed hands during the various games and the failure of many to redeem the same at the end of the party very materially aided in the financial success of the meeting.

Neil Adams, Reuben N. Trane, E. K. Campbell of the Chapter Relations Committee and their co-workers were congratulated on their splendid handling of the meeting and the complete success of the enterprise, both educationally and socially.

## Frank G. McCann Dies

Frank G. McCann, chief engineer of the Division of Heating and Ventilation, Board of Education of the City of New York, died on Wednesday, May 17, at his home 1616 East 10th St., Brooklyn, N. Y.

Mr. McCann was elected a Member of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS in 1903 and had the honor of serving as a member of the Council in 1914 and 1915 and as president of the New York Chapter in 1912. He was a regular and interested attendant at Society meetings for the past 30 years and his presence will be missed by his many friends in the profession. He was also a member of the *American Society of Mechanical Engineers.*

Born at Chicago, Ill., on Sept. 25, 1871, he was graduated from the Massachusetts Institute of Technology with the degree of S.B. and M.E. in 1896. After a few years' experience with the Boston Blower Co., Hyde Park, Mass., and Evans, Almirall & Co., New York, N. Y., Mr. McCann began his work with the New York City Board of Education in December, 1899, as mechanical draftsman. In June, 1902, he became chief of the Heating and Ventilating Division.

Mr. McCann originated the use of standard details and standard specifications for the work of school building and equipment. He was a well-known authority on the subject of school heating and ventilation and had contributed a number of articles to the trade papers, in addition to lecturing on heating and ventilation at the College of the City of New York.

In 1901 Mr. McCann married Louise C. Dralle, who survives him together with a son, Forbes E. McCann, to whom the Officers and Council express their sincere sympathy.

Funeral services were held on Saturday, May 20, at 11:30 a.m., at the Fresh Pond Crematory.

### H.P.C.N.A. Headquarters at Rockefeller Center

Announcement has been made by J. C. Fitts, secretary, that the headquarters of the *Heating and Piping Contractors National Association* and the office of the *Official Bulletin* are now located in Room 1401, at 1250 Sixth Ave., New York, N. Y.

### Canadian Distributor for Bell & Gossett

E. J. Gossett, president of Bell & Gossett Co., Chicago, Ill., advises that the Riley Engineering & Supply Co., Ltd., Toronto, Ont., has been licensed to manufacture and distribute their products exclusively throughout the Dominion of Canada.

### Marsh Associated with Lee Co.

Thomas A. Marsh has become a partner in the Ernest E. Lee Co., Chicago, Ill., manufacturers' representatives, with offices at 115 S. Dearborn St., according to a recent announcement. Mr. Marsh was for 10 years chief engineer of the Green Engineering Co., for 7 years western engineer for Combustion Engineering Corp., and for 3 years president of the Modern Coal Burner Co.

### Move Offices to Chicago

Effective May 1 the general offices of the McIlvaine Burner Corp. were removed from 749 Custer Ave., Evanston, Ill., to 663 W. Washington Blvd., Chicago, Ill.

# CANDIDATES FOR MEMBERSHIP

**The Constitution of the Society as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the JOURNAL of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Membership Committee as soon as possible.**

**When the Membership Committee has acted favorably upon a Candidate's application and assigned his grade, the Council shall** vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 8 applications for membership have been received and the names of these men and their sponsors are published in the following list.

**Members are requested to scrutinize the list with care. The Membership Committee, and in turn the Council, urge the members to assume their share of the responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.**

**All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.**

Unless objection is made by some members by June 15, 1933, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

| CANDIDATES | REFERENCES | |
|---|---|---|
| | *Proposers* | *Seconders* |
| BARRY, JAMES, JR., Vice-Pres., Elliott & Barry Engrg. Co., St. Louis, Mo. | C. A. Pickett | C. R. Davis |
| KOETZ, LESTER, Sales Engr., Zion Institutions & Industries, Inc., Zion, Ill. (*Advancement.*) | L. W. Moon | J. W. Cooper |
| KOHLER, WALTER J., JR., Supervisor, Kohler Co., Kohler, Wis. | J. R. Vernon | C. W. DeLand |
| | R. E. Hattis | J. J. Hayes |
| KRAMIG, ROBERT E., JR., Junior Member, R. E. Kramig & Co., Cincinnati, Ohio. | F. W. Hvoslef | J. S. Jung |
| | G. L. Larson | A. M. Freeman |
| LIBBY, RALPH S., B. C. Electric Power & Gas Co., Vancouver, B. C. | H. A. Pillen | I. B. Helburn |
| | E. B. Royer | R. E. Sproull |
| NITSCHKE, ROBERT C., Engr. and Draftsman, Socony-Vacuum Corp., New York, N. Y. | Walter Leek | H. J. McCreery |
| | R. E. Johnston | A. W. Givin |
| SYSKA, ADOLPH G., Partner, Syska & Hennessy, New York, N. Y. | R. C. Browe (*Non-Member*) | R. C. Winter (*Non-Member*) |
| | H. B. Lenau (*A.S.M.E.*) | S. Hargen (*A.S.C.E.*) |
| TOUTON, R. D., Tech. Dir., Bayuk Cigars, Inc., Philadelphia, Pa. | R. N. Ward | Russell Donnelly |
| | R. H. Carpenter | A. M. Alvord |
| | W. A. Bornemann | A. E. Stacey |
| | P. L. Davidson | J. deB. Shepard |

# Candidates Elected

**In past issues of the JOURNAL of the Society the names of the following men were listed as Candidates for Membership. The membership grade of each Candidate has been assigned by the Membership Committee and balloted upon by the Council. We are now instructed by the Council to post herewith, as required by Art. II, Sec. VIII, of the By-Laws, the following list of candidates elected:**

MEMBERS

CHAPIN, C. GRAHAM, Treas., Hopson & Chapin Co., New London, Conn.

HOLT, JAMES, Asst. Prof. of Heat. Engrg., Mass. Inst. of Tech., Cambridge, Mass.

JONES, EDWIN, Htg. & Vtg. Engr., Watt Plbg., Htg. & Supply Co., Tulsa, Okla. (*Advancement.*)

MEINKE, HOWARD G., Asst. Engr., N. Y. Edison Co., New York, N. Y.

ASSOCIATES

JENNEY, HUGH B., Sales Mgr., Dominion Boiler & Radiator Co., Toronto, Ont.

MACDONALD, EVERETT A., Br. Mgr., Spencer Heater Co., Boston, Mass.

JUNIOR

STRUNIN, JAY, Supt. and Est., Strunin Plbg. & Htg. Co., Inc., New York, N. Y.

STUDENTS

HANSEN, CARL J., Graduate Student, Agric. & Mech. College of Texas, College Station, Texas.

LEIGH, ROBERT LAWTON, Student, Michigan State College, East Lansing, Mich.

REYNOLDS, JACK A., Graduate Student, Agric. & Mech. College of Texas, College Station, Texas.

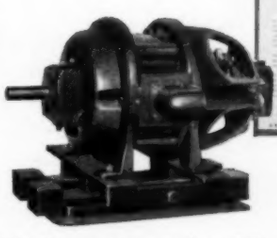
# *"....there's a motor under my bed!"*

"THE whir is most annoying! I hear it when I lie down. When I sit up, it stops!" A puzzled room clerk recently listened to such a complaint. He investigated.

No, the motor wasn't under the bed. In fact, the offender was finally located many floors away. Vibration, inaudible at the motor, had been transmitted and amplified by the building structure. A G-E *quiet* motor replaced it, and the trouble disappeared.

Situations like this combine to place joint responsibility for noise suppression on everyone concerned with the design and application of machinery in hotels, hospitals, clubs, etc., where quietness is of paramount importance.

General Electric recognizes its part of this responsibility, and, to reduce noise, offers a complete line of *quiet* motors and sound-isolating bases. Complete information on these new developments is available through any G-E sales office.



G-E *quiet* motor mounted on G-E sound-isolating base

Would you like copies of these valuable new publications, GEA-1695, "G-E Quiet Induction Motors", and GEA-1714, "G-E Sound-isolating Bases"? If so, write to General Electric, Dept. 6-201, Schenectady, N. Y.

200-715

GENERAL ELECTRIC

AIR CONDITIONING

"Made-to-Order Climate"

in all its branches by

STURTEVANT

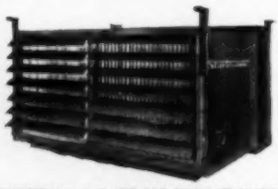
. . . pioneers in
Cooling and Air Conditioning

WHETHER it is one room of limited size or an entire building—comfort conditioning or industrial processing, there is Sturtevant air conditioning equipment which can be applied with complete assurance of the correct results. Not just one unit to handle all applications, but a full line of equipment which includes individual units to meet specific requirements, through to complete central systems.

STURTEVANT FILTICOOLER

There is the Filticooler, a unit which will filter, wash, humidify, and cool or dehumidify air. Its application is especially desirable for those areas such as food packing plants, and laboratories, where the conditioned air must be kept free of dust, dirt and bacteria. It can readily be fitted into the duct of an existing ventilating system and transform it into an air conditioning system, something to keep in mind for a modernizing project.

Another popular unit is the Suspended Type Air Conditioner. Consider just one feature of this unit. When operating as a cooler it does not frost, and the de-frosting cycle so necessary with the commonly conceived unit cooler is not necessary. Furthermore, it is installed suspended from the ceiling or beams, out of the way.



SUSPENDED TYPE AIR CONDITIONER

Other units operate as combination heaters and humidifiers, heaters and coolers, and humidifiers only for industrial, office and residential applications. They all play an important part in the present day modernizing programs, which are being planned. Let us work with you on any project you have or are contemplating.

Sturtevant Cooling and Air Conditioning Corp., a division of B. F. Sturtevant Co., is organized for engineering and installing complete systems in both the Comfort and Industrial fields.

Sturtevant

REG. U. S. PAT. OFF.

B. F. STURTEVANT COMPANY, HYDE PARK, BOSTON, MASS.

*"Made-to-Order Climate" for all purposes*


# World's Fair—

(*From page 291, Editorial Section*)

range of applications to which it is adapted.

### Little Theater in G-M Building Conditioned

Frigidaire Corporation has a most extensive display in the General Motors building which includes air-conditioning equipment. The entire water-cooling system in this building was installed by Frigidaire and the building's little theater (in which lectures will be given throughout the five months of the exposition) is air-conditioned with this concern's equipment.

### Shows Piping and Valve Progress

The exhibit of Crane Co. (Electrical Building) is planned to demonstrate the great importance of valves and fittings in industry and buildings. Those technically minded will be interested in the metallurgical display where progress which has been made in the use of metals which go into the manufacture of valves and fittings is shown. Attention is called to the fact that pressures as high as 6,000 lb can be controlled today, whereas a century ago 50 lb was considered extremely high.

### Illustrates Oil-Burning Equipment

In the Petroleum Heat and Power Company exhibit is a mural painting 20 ft long and 12 ft deep showing the heating plant of a large building to illustrate what happens to fuel oil from the time that it leaves the truck on the curb, down through the various stages and up to the time when it is consumed in the boiler. Another mural contains upwards of 25 paintings of individual buildings from coast to coast in the United States that are heated by this company's industrial and commercial oil burners.

One each of every type of oil burner that this company makes, is shown. Another spot of interest is a fuel-oil test table that shows just how oil is tested before being sold or delivered to the consumer.

### Shows Product Uses

With numerous operating models and dramatized diagrams, Union Carbide and Carbon Corporation and its subsidiaries will explain the uses of the products in its exhibit in the Hall of Science. Among these are compressed gases such as oxygen for medical use and for use with acetylene in oxy-acetylene welding and cutting, and many others.

### Stresses Year 'Round Conditioning

In a "garden of comfort," the American Radiator & Standard Sanitary Corporation will display its air-conditioning equipment. Among the equipment (which was the subject of an announcement recently made) is one type which cools the water by means of steam-jet vacuum refrigeration. This display emphasizes the point that

air conditioning is not only a cooling proposition, but that it involves humidification, cleaning, noise control, etc., as well.

The equipment will not only be on display but may be witnessed in operation, a large air-conditioning plant being partly housed in glass. Heating equipment will also be shown by this company in its building.

Other exhibits the readers of HEATING, PIPING AND AIR CONDITIONING will want to see are numerous. Among them might be mentioned the Johns-Manville building, the two wings of which house displays of the company's products; the central semi-circular center contains a large mural. The Link-Belt Company, in its exhibit, has 25 dioramas illustrating modern industrial methods; a five-sided obelisk in the center of the products display is devoted to featuring power-transmission equipment.

Informative exhibits are also sponsored by the *Copper & Brass Research Association* and the *American Gas Association*. Among the displays in the Travel and Transport group is that of the Baltimore and Ohio, which among other exhibits, has an entire six-car train completely air conditioned.

---

### New Standards Year Book Issued

The establishment during the past 12 months of 31 new national industrial standards affecting the construction, electrical, mining, oil, steel, radio, and almost every other major American industry is recorded in the recently-published *American Standards Year Book* of the American Standards Association. The *Year Book* is issued as a record of the cooperative achievement of nearly 3,000 scientists and engineers representing more than 500 national technical and trade organizations in the development of a unified system of basic technical standards for industry. The *Year Book* reveals that this work, which was started in 1918, has gone on without abatement during the past few years despite the depression.

Daniel C. Roper, United States Secretary of Commerce, in a foreword to the *Year Book*, points out the importance of industrial standards in commerce. "National recognition of such standards," Mr. Roper says, "will remove misunderstandings and expedite commercial transactions. Especially is this important in interstate and international trade when the buyer is unable to inspect personally and select the commodities offered by the seller."

Among the new national standards listed are:

Engineering and Scientific Charts for Lantern Slides (Z15.1-1932).

Approval Requirements for Flexible Gas Tubing (Z21.2-1932); for Hotel and Restaurant Ranges (Z21.3 1932); for Private Garage Heaters (Z21.4-1932); for Clothes Dryers (Z21.5-1932); for Incinerators (Z21.6-1932); for Gas-Heated Ironers (Z21.7-1932); for Conversion Burners in House-Heating and Water Heating Appliances (Z21.8 1933).

American Recommended Practice for Installation, Maintenance, and Use of Piping and Fittings for City Gas (Z27-1933).

Abbreviations for Scientific and Engineering Terms (Z10i-1932).


You can
Standardize on
Wagner Motors

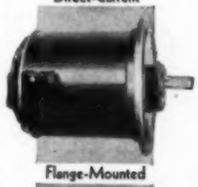
Repulsion-Start-Induction

Squirrel-Cage

Capacitor

Split-Phase

Direct-Current


Flange-Mounted

Vertical

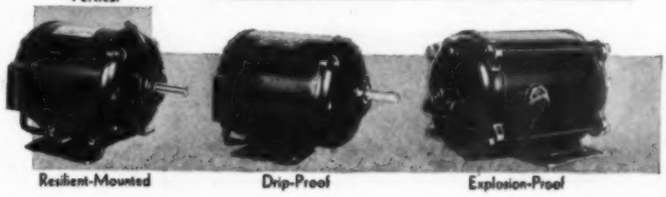
The Wagner line includes all types of small motors generally applied on motor-driven machinery, making it possible for you to standardize on Wagner motors. Whether alternating or direct current; single or polyphase; open, drip-proof, totally enclosed or explosion-proof; rigid or resilient-mounted, flange-mounted or built-in; sleeve or ball-bearing; horizontal or vertical—there's a Wagner motor now in existence, ready to be applied on the job.

*There are 25,000 different type-horsepower-speed combinations of Wagner motors (in ratings up to 400 hp). Certainly, your motor requirements are no greater than that!*

*For complete details, ask for Bulletin 167 describing Wagner small motors.*

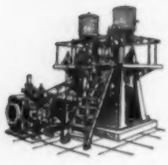
Wagner Electric
MOTORS
TRANSFORMERS
FANS BRAKES

Wagner Electric Corporation
6370 Plymouth Ave., St. Louis, Mo.
Gentlemen;
Please send copy of Bulletin 167 on small motors
If interested also in large motors, indicate here ☐
Name and Position
Firm
Address


Resilient-Mounted Drip-Proof Explosion-Proof

M333-6

## Experienced Engineering



Beginning in the early 80's, Frick Engineers pioneered with the Corliss engine driven compressors which remained the standard for the Refrigerating Industry for 35 years.

## Up-to-the-Minute Equipment

Today, Frick Refrigerating Machinery offers you the last word in smooth, dependable operation, accurate control of temperatures, low horsepower required, attractive appearance, and overall satisfaction.

## Data and Estimates

Including surveys of existing or proposed refrigerating systems are supplied without obligation to all interested parties. Discuss your cooling problems with a Frick Engineer now: Write

Frick Company
WAYNESBORO, PA. U.S.A.
ICE MACHINERY SUPERIOR SINCE 1882


# Servicing Filters—

(*From page* 303, *Editorial Section*)

coil to keep its contents at approximately 200 F.

The filter is then placed on the table section adjacent to the rinsing compartment and the operator removes the excess rinse water with an air hose and nozzle using a jet of air at about 50-lb pressure.

The filter is then ready to be recharged and is lowered in the oil-charging tank, which is filled with a special mineral oil. After the filter has become completely saturated, it is conveyed to the drain table and set in a tilted position in order to drain all excess oil from the media and frame work. Draining requires about 48 hours.

### Construction of the Cleaning Equipment

The entire filter-cleaning and charging equipment is fabricated of No. 10 gauge iron plates supported, braced and reinforced with structural shapes electric welded throughout. Field splices and joints were so located as to permit sectional delivery through existing doorways and were welded together after erection to make watertight joints.

The cleaning and rinsing compartments are of identical dimensions 18 in. wide, 52 in. long and 16 in. deep provided with a brass pipe grid centered 3 in. from the left side. The vertical header is 1¼ in. and the six laterals are ¾-in. diameter. The laterals are drilled with a total of 36—⅛-in. holes on 4 in. centers facing the filter.

Each compartment is provided with 7 ft of ¾-in. brass pipe coil supplied with steam at 40 lb pressure.

A Z-shaped baffle is welded to both ends and bottom to prevent the moving fluid from by-passing the filter.

The cover plates are removable and are provided with flanged openings to accommodate the filters.

A water drain section 8 in. wide is provided between the rinsing and charging tanks. The section drains toward a gutter at the front.

The oil-charging tank is 12 in. wide by 52 in. long by 16 in. deep, provided with a removable cover plate and a drain connection at bottom. The oil drain table gutter drains into the charging tank.

### Pumps Circulate Cleaning Fluid

The cleaning and rinsing compartments are connected to centrifugal pumps. Each pump has a capacity of 20 gpm at a 30-ft head and is constructed entirely of monel metal. Pumps are direct connected to ½-hp, 1800-rpm ball-bearing motors, with magnetic starters.

All controls (such as steam, water, air and drain valves) and electric push-buttons are conveniently located near the front of the equipment with extension stems where necessary.

---

Among the recent publications of the Engineering Experiment Station, University of Illinois, Urbana, are the Treatment of Water for Ice Manufacture, Part II, by Dana Burks Jr. (Bulletin No. 253) and The Production of Manufactured Ice at Low Brine Temperatures, by Dana Burks Jr. (Bulletin No. 254). The investigations reported in these bulletins were conducted in cooperation with The Utilities Research Commission, Inc.

# Modernize Piping—

(*From page 295, Editorial Section*)

### Fluid Flow in Pipe Lines

An applied knowledge of the fundamental principles of hydraulics is essential for every system involving piping mains carrying water or brine. Where possible, it is more desirable to use water in preference to brine if it will do the work, for it is cheaper, has higher specific heat and is less corrosive to piping.

Where brine is used, a careful watch is necessary on its gravity to prevent freezing at low temperatures, and its pH of alkalinity must be maintained to prevent excessive corrosion. The brine should not be heavier than necessary, for a lighter brine causes less frictional head loss and pumping costs.

The theory of fluid flow in pipe lines is too large a subject to be discussed in this article. Flow of refrigerating fluids in pipe lines—whether they be liquids such as water or brine or the vapors of volatiles—is affected by a number of flow factors. The rate of flow is caused by a pressure differential at the two ends of the line; otherwise no flow would exist. The impelling force of pressure differential is opposed by a resistance which is a function of the pipe diameter, its condition and also of the density, viscosity and mean velocity of the fluid. Obviously, an economic balance must be struck by studying these factors which affect flow, as many opportunities to reduce flow resistance by a change in the piping exist.

### A Friction Chart for Water

The two charts shown with this article will aid in checking up on brine and water piping. In cases where refrigeration is obtained by circulating cold water across a cooling surface, the quantity needed will depend on the conditions. In some instances a rise in temperature as high as 20 F or more may be permitted, where in others it may be limited to 2 or 3 F in order to maintain a suitable mean temperature difference between the water and the material to be cooled.

Suppose we have a 50-ton load of refrigeration to maintain a material at 68 F, ample well-water at a temperature of 55 F and our cooling surface will permit the use of large quantities of water with a 4-F rise in temperature. The water rate will need to be $50 \times 200 = 10{,}000$ Btu per minute. As each pound of water will absorb 4 Btu with a 4-F rise, this will be 2,500 lb per minute, or 300 gpm.

Fig. 1 shows a convenient water friction chart developed from Fanning's coefficient which is popularly used. From this chart we would probably choose to install 5-in. piping mains, in which case the 300-gpm rate would entail a friction-head loss of 2.3 feet per 100 lineal feet of straight pipe.

A comparison of piping costs vs head drop and power charges to overcome friction losses is necessary for a careful analysis; however, it will generally be found that it is economical to plan the size of main piping on water systems of less than 1,000 feet equivalent length of straight pipe, so that the friction loss is in the range of 2 to 5 feet per 100 feet of pipe.

NEW Emerson Capacitor Motors for Air Conditioning

SIMPLE in design, with the starting characteristics of an I R Motor, the New Emerson Capacitor Motors are super-quiet in operation. Special precision machining and extremely accurate centering of shafts provide unusual uniformity in air gap. There are no sliding contacts. And resilient mountings absorb vibration.

These motors specialized for hard service conditions—including refrigeration duty—have a maximum overload torque exceeding 100% and are cool-running (temperature rise less than 40° centigrade), even under continuous operation.

Extra large oil reservoirs are provided. There is no radio interference. Frames are interchangeable for A.C. and D.C. Sizes ⅛ to ⅓ h.p. with resilient mountings, ⅛ to ½ h.p. with rigid mountings.

Write for full information.

THE EMERSON ELECTRIC MFG. CO.
2018 Washington Ave., Saint Louis
9 South Clinton Street, Chicago
17 East 42nd Street, New York City

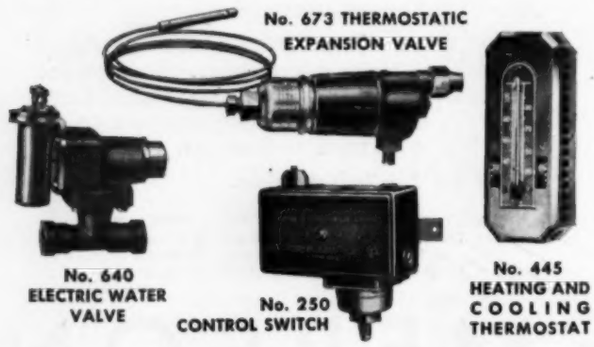
EMERSON MOTORS

*3 h. p. and smaller. For Fan Duty or Blower Service, Split Phase, Capacitor, Induction-repulsion, Polyphase and D. C.*

"GENUINE DETROIT"
No. 697
HUMIDISTAT

Here is a low-voltage, two-wire instrument which any experienced journeyman can install easily. Requires only ordinary bell wire to connect. Operates automatically and accurately to control the humidity in the air just as a thermostat controls the temperature. And the "Genuine Detroit" No. 697 Humidistat is not only efficient and accurate, but it is low in price, too.

Other controls in the complete line of "Genuine Detroit" units for air conditioning include, with others, No. 673 Thermostatic Expansion Valve, No. 640 Electric Water Valve, No. 250 Control Switch and No. 445 Heating and Cooling Thermostat. Write today for Bulletins Nos. F-39B, F-51, F-59, F-60, F-61.


No. 673 THERMOSTATIC EXPANSION VALVE
No. 640 ELECTRIC WATER VALVE
No. 250 CONTROL SWITCH
No. 445 HEATING AND COOLING THERMOSTAT

DETROIT LUBRICATOR COMPANY
Trumbull, Lincoln, Marquette & Viaduct
DETROIT, Mich., U. S. A.

Lubricators • Carburetors • Valves
Automatic Controls for temperature, pressure, humidity
Refrigeration, Oil Burner and Heating Accessories

### A Chart for Brine

Refrigeration brines in popular use are water solutions of sodium chloride or calcium chloride. The latter is used in the majority of cases on account of its less corrosive action and especially for low-temperature work. Calcium chloride brine may be made as strong as a specific gravity of 1.28 and will freeze at approximately —53 F. It is rarely used for temperatures lower than —40 F. Sodium chloride brine may be made as strong as a specific gravity of 1.23 and will freeze at approximately —6 F. It is rarely used for temperatures lower than —2 F. Either one becomes sluggish and viscous several degrees above their freezing points, which accounts for this choice.

The size of brine mains to be used for a particular problem must be chosen on the basis of friction drop, as in the case of water. Brine behaves somewhat similarly to water, but its friction loss increases with density as well as inversely with temperature, especially near the eutectic point, where viscosity is such a large factor inasmuch as this is the freezing point of the brine solution. As the brine is lowered in temperature and approaches this point, a large part of the solution freezes into crystals, which gives it a mushy appearance. This is what causes the high viscosity and consequent high friction drop. Fig. 2 has been prepared to show a chart of multipliers for use with sodium- or calcium-chloride brine to be used in conjunction with any reputable water friction chart.

Assume a system using calcium-chloride brine of 1.200 specific gravity for a 50 ton refrigeration load with the brine to be circulated at a temperature of 0 F and a 5-F rise permissible:

50 tons $\times$ 200 Btu per minute = 10,000 Btu per minute.
$10{,}000 = W \times 0.68 \times 5$.
$W$ = 2,942 lb per minute = 295 gpm = amount of brine circulated.

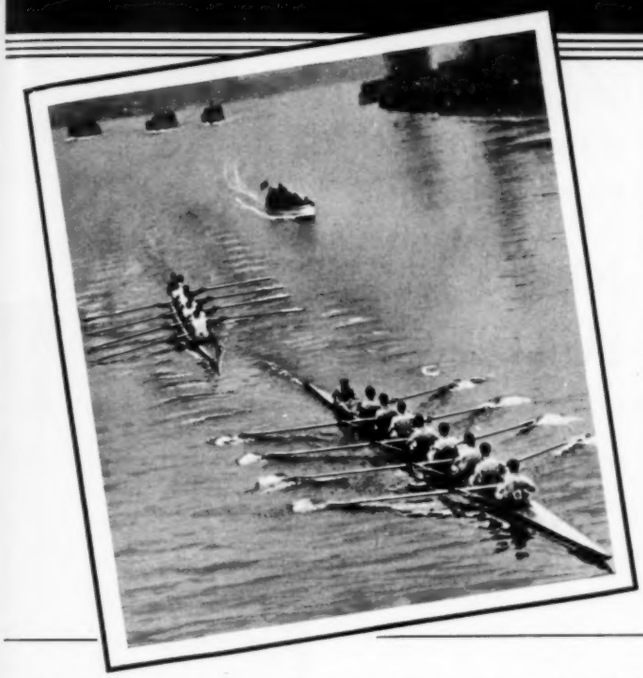
In this case we would probably choose to use 5-in. brine mains. From the water friction chart, Fig. 1, the loss (if water is flowing) is shown as 2.3 feet per 100 lineal feet of pipe. By reference to the chart for calcium-chloride brine, Fig. 2, the multiplier is found to be 1.48. Therefore, the friction loss for brine = $2.3 \times 1.48 = 3.42$ feet per 100 feet of length, which is within an economical range.

### Air Conditioning Papers in Book Form

The papers presented at the Western Conference on Air Conditioning (held last February at the University of California under the sponsorship of the San Francisco section of the *A. S. M. E.*) have been published in a paper-covered book of 70 pages (8½ x 11). Copies are available from A. P. Hahn, Secretary-Treasurer, *A. S. M. E.*, 206 Sansome St., San Francisco, at $1.00.

Contents include the opening remarks of the chairman, Prof. B. M. Woods, and the following papers: Basic Theory of Air Conditioning, Psychrometric Chart and Its Use, Physiological-Psychological Basis of Comfort, What Is Comfort?, Cooling Fundamentals, Cooling With Ice, Insulation, Heat Capacity and Heat Transfer, Los Angeles Weather, Medical Aspects, Design Procedure, Filtration, Control and Regulation, Collaboration of Architect and Engineer, Sun Effect and Surface Temperatures, Heat Transfer in Unit Coolers, Industrial Natural Ventilation, and two papers on cooling homes.

# Precision Counts in Flanges too



It's the stark, deadly precision of flashing sweeps and bending bodies that glorifies the crew race. It's this same unrelenting precision that makes Harrisburg drop-forged flanges the "finest made in America." The threads of these superior flanges are full and uniform, perfect in height, angle and gauging. Specify "Harrisburg" where tests are toughest.

*Sales Agents*

W. P. PAUL CO. . . . . Drexel Bldg., Philadelphia
S. C. MEAD . . . . . 160 No. La Salle St., Chicago
MID-CONTINENT SUPPLY CO. . . . . Fort Worth, Texas
DUCOMMUN CORP. . . . . Arcade Station, Los Angeles

**HARRISBURG PIPE & PIPE BENDING CO**
**HARRISBURG, PENNA.**

**HARRISBURG • DROP FORGED • FLANGES**

SIMPLE AND INEXPENSIVE

. . . pump attached directly to any standard motor . . . pump bearings, base and coupling eliminated . . . only one stuffing box . . . no pump lubrication necessary . . . all parts accessible without disturbing piping . . . easily installed in any position . . . very compact . . . such outstanding improvements found nowhere else . . . O. K. for any small pumping requirement.

Write for Bulletin 100A.

AMERICAN STEAM PUMP COMPANY
BATTLE CREEK, MICHIGAN

# AMERICAN-MARSH

## MOTOR UNIT

## Centrifugal —Pumps—

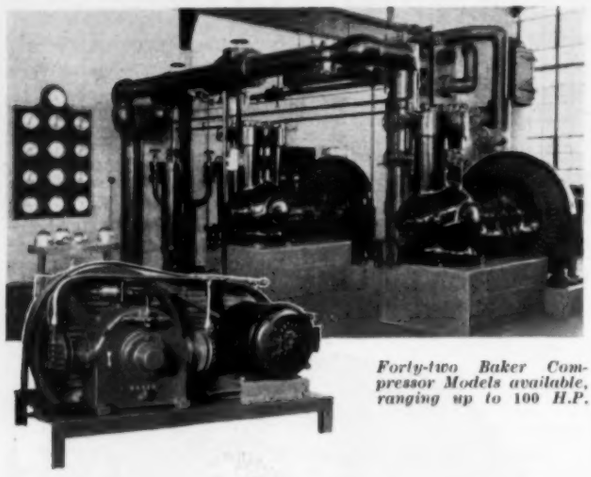
FIVE SIZES: 1-inch to 3-inch.

CAPACITIES: 5 to 450 g. p. m.

HEADS: up to 120 feet maximum.

# *Successful* AIR-CONDITIONING

## *Demands a Unit of Exactly The Right Capacity*



*Forty-two Baker Compressor Models available, ranging up to 100 H.P.*

## *You Can Supply Every Need from the*

# BAKER *COMPLETE LINE*

THE Baker line is so complete and well graduated in range that it allows the use of *exact* specifications for your every requirement—"tailor made" capacity for any air-conditioning job. And remember, Baker Quality Refrigeration insures these air-conditioning essentials . . .

**Automatic Control**—Set to any desired point of cooling and dehumidification, Baker units are fully automatic in operation.

**Endurance**—Built to withstand the hardest kind of service.

**Flexibility**—Baker units deliver the required capacity at the right time, and at a worthwhile saving in operating costs.

**Precision Made**—Baker manufacturing standards require accuracy to 1-10,000th part of an inch.

*Consult a Baker Engineer about your problems—he will gladly furnish estimates and data on any type of installation*

# BAKER

**ICE MACHINE CO., Inc.**

1570 EVANS ST. OMAHA, NEB.

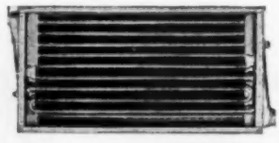
FACTORIES: Omaha Seattle Ft. Worth Los Angeles

# AEROFIN

IS THE HEAT-SURFACE FOUND IN THE

# NEWS BUILDING

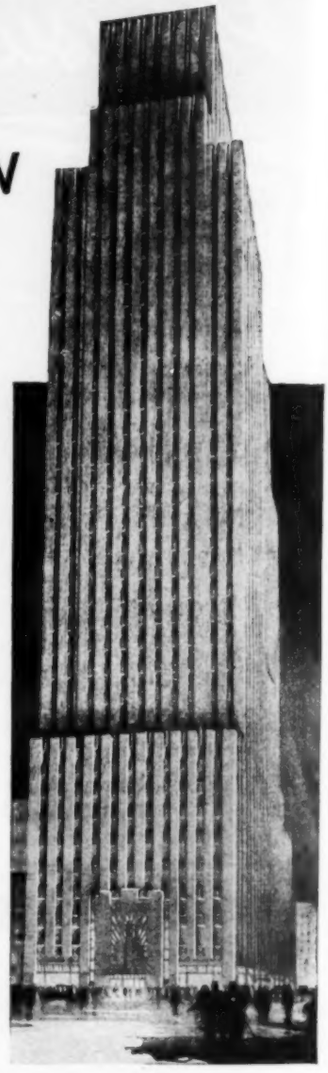
NEW YORK CITY



*The Standardized Light-Weight Fan System Heat-Surface*

**4 Types 196 Standard Sizes**

A comprehensive and helpful Bulletin will be mailed without charge upon request to Newark. Please use your business letterhead and ask for Bulletin 32.



Raymond M. Hood
John M. Howells
*Associate Architects*

Hegeman Harris Co.
*General Contractor*

Jaros & Baum
Lockwood Greene Engineers, Inc.
*Engineers*

Alvord & Swift
*Heating Contractor*

This is not happenstance. *AEROFIN* is selected by America's foremost Architects and Engineers because of its *proved* superiority. Pioneering lightweight, non-corrodible, *unit* Fan System Heat-Surface years in advance *AEROFIN*, designed and constantly improved by Fan Engineers, is still years in advance. Newark will be glad to send informative and appropriate publications upon request. Any Office will gladly render prompt, efficient, technical cooperation.

*AEROFIN is sold only by Manufacturers of Nationally Advertised Fan System Apparatus. List upon Request*

AEROFIN CORPORATION
850 Frelinghuysen Avenue
Newark, N.J.
Chicago Detroit New York Philadelphia

## Isolation—

(*From page 305, Editorial Section*)

plete and impartial discussion of the various methods of isolation and the emphasis on the necessity of adequate isolation. May I, however, take this occasion to call to attention one point. In speaking of various materials for isolation, it is stated. "It is important, considering endurance, that organic materials such as cork, rubber and felt be kept oil-and-water free; otherwise their useful life will be shortened unduly."

It is our experience that natural cork is unaffected by water and oil. As a matter of fact, we treat our cork plates with oil before shipment, and in the printing industry, where cork plates are used to a great extent, they are frequently installed in the drip pan of the presses where they are constantly immersed in oil. If anything, this condition increases the life of the natural cork. As far as water is concerned, we similarly have nothing to fear and cork in bales is sometimes stored out-of-doors, where it is periodically subject to rainstorms and the elements.—*B. A. Doane.*[1]

There are two general kinds of cork—one the untreated natural bark, the other a treated product made up of cork particles compressed or bound into slab form. The latter may be an excellent heat insulator when protected by masonry and water proofing as applied to a cold-storage warehouse, for instance. As applied to the use of this manufactured or assembled type of cork my point regarding protection from water and oil would hold. When natural cork is considered, however, it is fair to say that experience shows no deterioration for this material under ordinary water and oil contact.—*Samuel R. Lewis.*[2]

## Tappings for Gage Piping

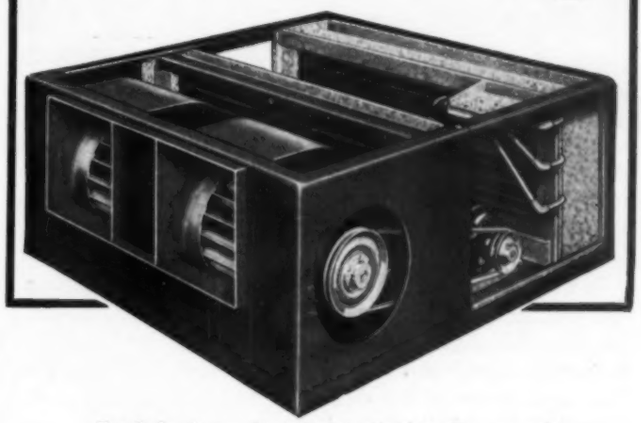
SOME recent experiences in industrial piping maintenance work have stressed the importance of giving attention to gage pipes and other small-size pipe connections on high-pressure piping and pipe lines where a shut-down on short notice is not practical. Many times a ¼-in. pipe tap is made for a gage, as it is advisable to take the gage connection from the large pipe to get an accurate reading, instead of the branch line. The small size connection is likely to be broken off easily. Main pipe lines are usually of pipe that has a wall thickness that will permit safely a larger size tapping. It is better to make the tapping ½-in. and use a heavy pipe nipple or a special nipple with a smaller size bore to make the connection rigid and strong.

Impurities are carried in steam, water and other liquids that cause stoppage in small pipes, even when the small pipe is connected to the top of the larger pipe. When a gate valve is used the pipe can be disconnected above the valve and the nipple, in some cases, rodded out, without shutting down the larger pipe line.

The small and apparently minor details of a large piping system frequently cause more trouble to properly maintain the equipment than the larger valves and fittings.—*W. H. Wilson.*[3]

[1] The Korfund Company, Inc., New York City.
[2] Consulting Engineer, Chicago. Member of Board of Consulting and Contributing Editors.
[3] Member of Board of Consulting and Contributing Editors.


# Comfort-Conditioning



*Buffalo 4-ton Unit with Casing Removed*

**Comfort Conditioning means just what it says—comfortable indoor temperature all year 'round. The new Buffalo Comfort Conditioner, designed particularly for offices, stores and restaurants, provides comfortable temperatures and positive air circulation at all times. Suspended from the ceiling, these units take only twenty inches headroom. Sound absorbing outlets provide distribution without drafts.**

**Two coils are provided—a cooling coil for cold water, brine, methyl chloride or freon, and a heating coil for steam or hot water.**

**The unit has an insulated casing (to prevent sweating) neatly trimmed with metal angles and corners. Three sizes give wide range of capacities.**

**If you have a comfort conditioning problem, write today for full information on Buffalo Comfort Conditioner.**

## Buffalo Forge Company

171 Mortimer St., Buffalo, N. Y.

In Canada: Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

"Buffalo" Comfort Conditioner Cooling-Heating

## Stores Ice—

(*From page* 297, *Editorial Section*)

The cost of an ice-tank installation, without steam reheating, would be:

| | | |
|---|---|---|
| First cost, $1,000 | | |
| Amortization and interest (10 yrs. @ 14%) | 140 | |
| Ice (600 tons at $3.75) | 2,250 | $2,390 |

The above costs are compared on a four-month basis and allow for daily use of the mechanical plant and the use of cake ice only when definitely needed. In addition, the operating costs of the mechanical plant include the requirements for the circulating drinking water system. The costs are based on a ten-year amortization as a prudent investment policy. The life of the apparatus should be far greater, however.

It will be noted from this comparison that the mechanical storage plant has proved to be more economical than ice on a job directly in the field in which ice has often been considered as the most satisfactory solution, and that in addition to the direct operating cost shown, the plant has the advantages of instant availability and ease of operation.

It would seem to the author that refrigerating engineers would do well to consider this problem of ice accumulation with a view to obtaining designs that will allow ice building at high suction pressures, ice melting at an adequate rate, and minimum space requirements. The idea is now entirely feasible using the ordinary apparatus at our disposal.

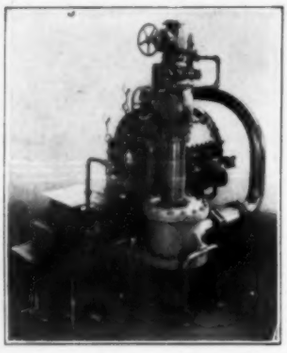
The use of air conditioning in industrial plants, large office buildings, large theaters, department stores, restaurants, etc., is well established and offers advantages entirely consistent with first and operating costs. Small stores, offices, and similar buildings (including residences) offer a promising field but with the possible exception of small stores in congested metropolitan areas it is the author's belief that present costs, both first and operating, do not economically justify these installations. These costs can and must be reduced. The mechanical ice-accumulator system herein outlined shows one approach to this problem.

## Product Improvement—

(*From page* 293, *Editorial Section*)

film developing it is so integral with the air-conditioning that its description is necessary to paint a complete picture of the laboratory operation. The refrigerating unit used in conditioning air is also used to supply cold water for maintaining an accurate control of the temperature of the developing and fixing solutions.

Each developing machine has its own developing solution tank and an independent circulating system. The solution is pumped from this tank to a tank in the developing room and then back to the collecting tank. The collecting tank is equipped with coils communicating through automatically-controlled three-way valves to cold- and warm-water circulating systems. The warm-water circulating system includes a steam-heated interchanger, while the cold-water circulating system passes through an interchanger to which cold water is supplied from the refrigeration system.

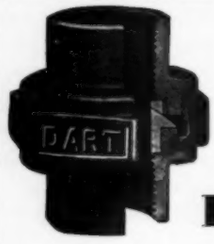
**A VILTER ROTARY OF THIS TYPE, USING FREON IS INSTALLED IN THE AIR CONDITIONING PLANT AT "Old Heidelberg Inn" *at the* Chicago World's Fair**

Vilter Rotary Compressors used in supplying refrigeration in air conditioning plants wherein Freon is used as a refrigerant, are described in Vilter Bulletin No. 45. Freon being non-toxic, non-inflammable, and non-corrosive, is a "safe" refrigerant for this work, and a Vilter Rotary Compressor is ideal for this class of service.

THE Vilter MFG. CO.
2124 S. FIRST ST.
MILWAUKEE, WIS.

BUILDERS OF REFRIGERATING MACHINERY FOR 30 YEARS

**DART UNIONS**




***offer***

**DOUBLE PROTECTION**

Specification engineers are quick to realize the superiority of DART UNIONS. They know that when they standardize on DART UNIONS they get

*Double the wear. . . . Double the protection. . . . Double installation ease.*

It's the *two bronze seats* that make these outstanding features possible. *Two bronze seats* perfectly ground to a ball joint.

*Write DART into your piping specifications and see for yourself.*

**E. M. DART MFG. CO., Providence, R. I.**

*Sales Agents*
THE FAIRBANKS CO.
New York Branches

*Canadian Factory*
DART UNION CO., Ltd.
Toronto, Canada

Individual automatic thermostats for each developing solution tank maintain the accurate control necessary. Needless to say, the rather complicated piping system was designed most carefully. Whatever the degree of accuracy of the thermostat, unless the heat interchanger and the circulating systems are properly designed, it will be impossible to maintain the accurate temperature control desirable.

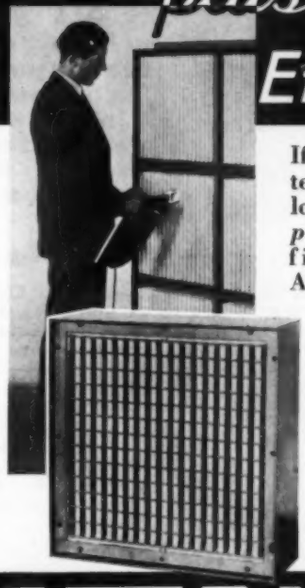
The proper temperatures, humidities and pressures to use for film-developing are well established and it is the job of the air- and liquid-control systems to produce these conditions. In the process, the film goes first through the loading and breakdown room, in which the temperature is kept at 75 F and the humidity at 65 per cent. From there it is sent to the developing room, where the temperature and humidity are also 75 F and 65 per cent. The developer solution used is held at a temperature of 66 F. After passing through this solution the film is washed in a second solution at 66 F. It then proceeds through the drying cabinet which is served by the individual recirculating unit. In the cabinet the temperature of the air is kept at from 75 to 80 F with a relative humidity of 50 per cent. (The time required for negative film to pass through the developing machine and drying cabinet is from 45 minutes to one hour, the time necessary for positive film is 15 to 22 minutes. If the rate of drying is too great, the quality of film is impaired, and in extreme cases the film may come out curled and brittle and be unfit for use. Faster times than those mentioned are often used in the rapid production of newsreel print.) The film is then perforated in a room held at 75 F and 65 per cent humidity.

This process applies only to negative film. Positive film is subjected to a few more operations. The positive film is printed on raw stock from master negatives in a room at 70 F and 70 per cent. (The humidity is held sufficiently high to prevent the generation, or at least the discharge, of static electricity in the printing machines. These discharges, uncontrolled, very often seriously fog the positive. Another object of controlling the air in the printing room is to prevent a change in the size and length of film, which would make synchronization of the sound-track negative and the positive print difficult.) It is then developed, washed and dried under the same conditions as the negative film, except in a shorter time as mentioned. It is then cut, joined and polished in 75 F and 65 per cent rooms. The rooms in which the film is projected for inspection are conditioned only for the comfort of the observers. The storage and shipping rooms have no conditioning.

Pressures are maintained in the drying cabinets to prevent the room air from entering and changing the conditions of drying. In this laboratory the developing rooms themselves are supplied with clean, conditioned air, and, therefore, any infiltration of air into the cabinets should not cause difficulty because of dust. However, by maintaining pressures within the cabinets this remote possibility is removed.

It is quite important to be able to regulate the individual cabinets separately because not only is the developing time being continuously changed in each cabinet due to the changes which occur in the film during development, but the drying time changes as well. Experience also has shown that certain types of film are more difficult to dry than other types.

LOWEST COST *plus* Highest Efficiency!



If it's economy you are interested in — there is no lower priced (initial cost *plus* maintenance) air filter made than the ANNIS.

In addition, you get an air filter of the highest possible efficiency—100%.

What more could you ask than "Lowest Cost *plus* Highest Efficiency."

*It will pay you to get the facts—write for Bulletin F-320.*

COPPUS ENGINEERING CORPORATION

374 PARK AVE. WORCESTER, MASS.

ANNIS

HOFFMAN

*now offers the* MOST COMPLETE LINE *of* STEAM HEATING SPECIALTIES

VALVES

TRAPS

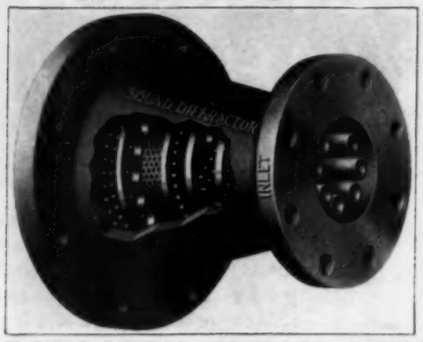
PUMPS

FOR EVERY TYPE OF STEAM HEATING SYSTEM

For full information See Your Wholesaler or write to

Hoffman Specialty Co., Inc., Waterbury, Conn.

**NOISE**




**This is a device for preventing NOISE made by steam passing through a pressure reducing valve. No moving parts.**

**Send for bulletin**

**BOYLSTON STEAM SPECIALTY CO.**
**126 WEST ILLINOIS STREET, CHICAGO, ILLINOIS**

*Convectofin Heating Element*

**15 PIECES LESS MEANS DOLLARS SAVED ON INSTALLATION**

Only CONVECTOFIN *the* BUILT-IN HEATER makes such reduced costs possible. Saves in materials, in handling, in effort, and time. Also assures unfailing results. Not a promise or claim. Real, faithful capacity. Our data on Certified Performance gives proof. Write for your copy.

**COMMODORE HEATERS CORP.**
11 West 42nd St. New York City

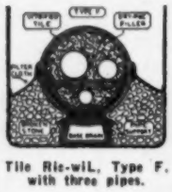
Ric-wiL Tile Conduit, Type F, insulated with Dry-paC.

**RIC-WIL TILE CONDUIT**

with Loc-liP Side Joint, is a complete Conduit System providing ample protection for underground steam and hot water pipes. Completely engineered, it eliminates extras.

**DRY-PAC INSULATION**

is waterproofed, thus keeping steam pipes dry and maintaining the highest thermal efficiency. Write for complete details.



Tile Ric-wiL, Type F, with three pipes.

**THE RIC-WIL COMPANY**
1562 Union Trust Building • • • • • Cleveland, Ohio
Branches: New York - San Francisco - Chicago
AGENTS IN PRINCIPAL CITIES
REG. U. S. PAT. OFF.
**RIC-WIL**
CONDUIT SYSTEMS FOR UNDERGROUND STEAM PIPES

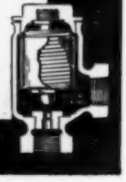
**LOOK INSIDE YOUR PLANT FOR BIG SAVINGS**

If you use steam for process work or heating, you can save real money by properly trapping the coils and lines.

Untrapped lines or wasteful, obsolete steam traps allow live steam to escape. Steam means fuel, and fuel costs money. Save it by using the Sarco Individual Trapping System.

Write for Catalog O-95 and free trial offer.

SARCO COMPANY, INC.
183 Madison Ave., New York City
Branches in Principal Cities



**SARCO STEAM TRAP**


# Dust Collectors—

(*From page 304, Editorial Section*)

Radius of bends should be at least 1½ times, and preferably 2½ times, the pipe diameter to avoid excessive resistance losses, and the metal thickness made at least two gauges heavier than that required for straight pipe of the same size.

Eliminate turns wherever possible, thus reducing resistance.

Piping should be so proportioned as to maintain the velocity desired and abrupt changes in size should be avoided. Such changes should be made with an eccentric taper flat on the bottom, the taper being at least 5 in. long for every inch change in pipe diameter. Excessive velocities cause abrasion and holes soon appear, and they must either be patched or the piping replaced. If the air velocity varies in different sections of the line too greatly, dust is apt to settle out and the pipes will soon fill up.

All piping must be adequately supported and should be constructed of the proper gauge material.

Care should be used in assembling so that all gaskets are trimmed flush inside, that circular laps run in the direction of air flow, and that clean-outs and blast gates are provided where necessary. Outside longitudinal laps should be placed on the bottom.

All branches should enter the main line at an angle not greater than 45 degrees and their bottoms should be on the same plane as the bottom of the main and not half-way up the side. The reason for this is that when the fan is shut off, whatever dust remains in the system settles to the bottom of the pipes and if the bottoms are kept level this dust is easily moved when the fan is started again. However, if the bottoms of the pipes are not on the same plane, a pocket is formed which soon becomes filled with dust and results in undue resistance, loss of suction, and frequently the failure of the pipe due to the heavy weight of material it may contain.

Foreign material such as rags, oily waste, gloves, papers, and fruit skins should not be allowed to enter dust pipes. This may be prevented by providing coarse wire screens over the hood intake.

Galvanized piping, preferably of copper-bearing steel, should never be painted until exposed to the weather for at least six months unless it is first treated with some solution to cut the acid which remains on its surface from the galvanizing process. If not removed, this will eat away the coating of paint.

### Care of the Fans and Motors

Fans should never be operated when the doors of the dust arrester are open unless the blast gate nearest the fan is nearly closed. In such cases the fan takes on a full load and the motor soon burns out. Many times dust-collecting troubles have been traced to the fact that the fan was so wired that it operated in the reverse direction, or that in making repairs or replacements the impeller was reversed.

A variable-speed motor is a distinct advantage when it is desired to separate dust into various sizes for further use. Direct-connected motors and fans should be used when motors of proper speed are available and should be equipped with ball bearings.

Care should be taken in lubricating fan bearings that all excess oil is wiped up, as this sometimes runs along the shaft and is drawn into the fan casing and then onto the impeller blades. If there are dust leaks, the blades become coated and out of balance. The fan

should be placed as close to the dust arrester as is practical to reduce resistance losses, and a blast gate should be provided near the fan to regulate air flow.

### Preventing Fire in Collection System

In the collection of hot material, such as sand from foundry shake-out floors, steel chips, or grinding dust from machine shops, there is always the danger of fire inside the arrester. Fires may also be caused by cigarettes carelessly tossed into exhaust hoods or from men smoking in dust arresters when repairs or inspections are made. A spark arrester, consisting of screens of low air resistance, may be used to prevent sparks and hot material from entering the main case until they become sufficiently cooled. The spark arrester is placed in the main pipe line just before it enters the dust side of the collector. Special slow-burning cloth screens may also be used in the dust arrester. Additional protective equipment, such as dry sprinkler systems, may be installed in both spark arrester and dust arrester to prevent fire spreading, but once a screen is wet it is damaged beyond repair and replacement is necessary. Smoke vents may also be provided in the roof of the arrester which may be removed by firemen to allow smoke to escape after a fire is under control. Easy access to the case should be provided by means of tight-fitting doors in both clean-air and dust chambers.

### Make Regular General Survey of Plant

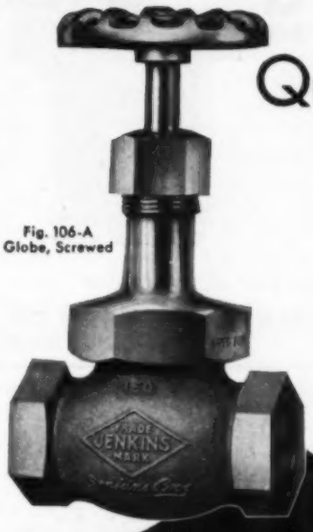
It is suggested that plants having dust-collecting equipment employ a competent engineer at regular intervals to make tests of the fan equipment and general ventilation, obtain air samples and determine dust counts in questionable areas of the plant, and submit recommendations with these findings so that the plant may be able to prevent undue dustiness in connection with its manufacturing processes and will have a permanent record of dust conditions which may prove extremely valuable as evidence in industrial claims for compensation. It is also advisable to have proposed ventilating and dust-handling problems carefully checked over and reviewed at these times and recommendations obtained before new equipment is purchased or installed.

### Summary

Cloth-screen-type dust arresters are used to collect and confine dust and to enable recirculation of filtered exhaust air into the factory, with consequent saving in heat. In this article (May and June installments) the operation of such a system is described and the maintenance difficulties caused by leaks, dirty screens, and neglecting to empty the hoppers are discussed, with special attention given to increasing the life of the screens and the efficiency of the system as a whole. A method of controlling screen rapping by the pressure drop through the arrester is proposed.

Points to be observed in designing, erecting and maintaining arresters and the layout of the piping (with reference to the prevention of wear to both pipes and screens by the use of classifiers) and the care of fans and motors are given.

Obtainable through your supply house




Quality pays even today

There is QUALITY in Fig. 106-A Jenkins Bronze Globe Valve ...extra deep stuffing box...slip-on stay-on disc holder...one-piece screw-over bonnet...Jenkins Disc.

JENKINS BROS.
80 White St., New York, N.Y.
Bridgeport, Conn., Boston, Mass.
Chicago, Ill., Philadelphia, Pa.

Jenkins
BRONZE IRON STEEL
VALVES
Since 1864

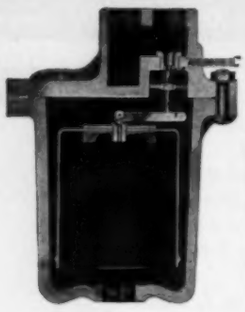
Always marked with the "Diamond"

VISIT THE
6th
CHICAGO
POWER SHOW
June 27-29

STEVENS HOTEL
Exhibition Hall
DURING
"ENGINEERING WEEK"
Right in the heart of the activities.
It will pay you to see these exhibits.

For information write
6th MIDWEST ENGINEERING & POWER EXPOSITION
308 West Washington St., Chicago

**STRONG**
**STEAM TRAPS**



Small Size
Large Capacity
Non-Clogging
Non Air-Binding
Anti-Balancing

*Guaranteed for One Year Against Wear*

**THE STRONG, CARLISLE & HAMMOND CO.**
1392 WEST 3RD ST. CLEVELAND, OHIO

**TU-WAY DEFLECTS the FULL Air Flow**

New No. 3 Improved type

Equal volume in two directions. Full capacity of duct. One piece cast iron head built low to prevent interference with seats.

Screw-type adjustment-damper constructed to eliminate all obstructions to air flow. These are reasons why the Knowles Tu-Way Air Deflectors are remembered in so many specifications.

Construction diagram upon request.

KNOWLES MUSHROOM VENTILATOR CO.
41 North Moore Street New York, N. Y.

***By the best authorities***

**Good, sound, practical, information which will help greatly in simplifying your work and which is written by the industry's best authorities. This best describes the contents of every issue of HEATING, PIPING *and* AIR CONDITIONING.**

HEATING, PIPING *and* AIR CONDITIONING
1900 Prairie Avenue, Chicago, Ill.

***To be thoroughly informed subscribe today. Three Dollars a year.***

**ARMSTRONG TRAPS** (Original Inverted Bucket Type)

*For any capacity and for any use*

Catalog on Request

ARMSTRONG MACHINE WORKS
574 Maple Street
Three Rivers, Mich.

*Stocks in all Principal Cities*

# Equipment—

(*From page* 310, *Editorial Section*)

effects, it is possible to get the net temperature effect of the radiated energy alone.

A number of curves showing the remarkable difference in reading between an ordinary thermometer and this "radiation-differential" thermometer have been prepared by Mr. Lindsay.

## Burner for Heavy Oils, Tar

A steam-atomizing burner which can handle fuels such as heavy oil, tar, pitch, and acid sludge (as available in quantities in petroleum refineries) has been developed by The Babcock & Wilcox Company, 85 Liberty St., New York City. Steam is admitted to an annular space around the central fuel barrel and is projected across each outgoing stream of fuel at the nozzle plate, to effect complete atomization and result in a short turbulent flame when used with the standard B & W burner register. A single nozzle plate is used for all capacities from the maximum to minimum ratings, variations in capacity being accomplished by varying the fuel and steam pressures. The company states that fourteen burners of this type have been in successful service, in a large oil refinery, for seven months handling most of the time, refinery waste products such as heavy oils, tank bottoms, acid tar and acid sludge, and that the results obtained were very satisfactory.

## Safety Device for Gas-Pilot

A new automatic safety device for gas-pilot control is now available from the Powerstat Corporation, 557 Market St., San Francisco, Calif., which is, according to a recent announcement, "a mono-metal alloy device with practically unvarying speed under widely varying temperatures and with a fatigue point beyond the temperatures of ordinary fireboxes." It forms the activating member in conjunction with a new carbureting pilot-light burner designed to have the inherent ability to purge itself of gas gum.

Two other products recently announced by this company are a line of gas and liquid strainers and a sealing gum for artificial, natural or propane gas lines.

## Three New Bearing Types

According to an announcement by the Gatke Corporation, 228 N. LaSalle St., Chicago, a complete line of this company's bearings for general machinery uses is now offered; formerly, these were made exclusively for steel-mill service. The bearings are non-metallic and are composed of a special textile base impregnated with synthetic resins, moulded under high pressures and manufactured in a variety of shapes and sizes. Three basically different materials are used for various services—where bearings are water lubricated, where they are oil lubricated, and a self-lubricating type.

## Recent Trade Literature

*Air Conditioning for Railroad Cars:* American Car and Foundry Company, 30 Church St., New York City. Two 4-page pamphlets, one devoted to thermo-gravity (ice) and the other to thermo-mechanical (compressor) air-conditioning systems. Both are available in summer and in summer-and-winter types.

*Brewery Equipment:* Allis-Chalmers Manufacturing Company, Milwaukee, Wis. Equipment for the modern brewery and malt house, a 12-page bulletin illustrating and describing steam-turbine and alternator units, steam-engine and generator sets, motors,

rotary air compressors, V-belt drives, centrifugal pumps, malt mills and miscellaneous equipment.

*Boilers and Water-Level Control:* Kisco Boiler & Engineering Co., 3822 Olive St., St. Louis, Mo. Two folders describing the features and advantages of automatic water feeding, and a system for returning condensate to the boiler and supplying preheated water. One also describes coal and gas-fired boilers for industrial use, and heat exchangers for drying rooms, curtain dryers, carpet drying, heating, etc.

*Heating Equipment:* Hoffman Specialty Company, Inc., Waterbury, Conn. A 12-page catalog of equipment for vapor and vacuum systems, well illustrated and containing numerous diagrams. The features of an adjustable orifice modulating valve, bellows-type thermostatic traps, high-pressure thermostatic traps, a drip trap, heavy-duty float and thermostatic traps, differential-loop equipment, boiler-return equipment, etc., are described. The diagrams show applications and typical connections.

*Manhole Ventilators:* Coppus Engineering Corporation, 344 Park Ave., Worcester, Mass. Leaflet announcing a portable gasoline-engine driven manhole ventilator for ventilating confined working spaces.

*Motors and Motor Bases:* General Electric Company, Schenectady, N. Y. Quiet induction motors, a 4-page bulletin describing motors especially designed and tested for quiet operation for driving ventilating fans and similar applications; squirrel-cage and wound-rotor types, ½ to 50 hp; single-phase, ½ to 10 hp—constant or adjustable-varying speed. Control is also discussed. A 2-page data sheet describes and illustrates sound isolating motor bases for floor mounting, with belt adjusting features.

*Process-Steam Boilers:* Commonwealth Electric and Manufacturing Co., 93 Boston St., Boston, Mass. Electric-heated full-automatic steam boilers for process steam, a 12-page booklet describing boilers for pressures up to 200 lb and in six sizes from 7½ to 90 kw, ¾ to 8¾ boiler hp. Complete specifications and descriptions are given and auxiliary and control equipment is discussed. Considerable information is given on applications and selection. A 4 page pamphlet gives similar data for miniature electric steam generators in 2, 3, 4 and 5-kw sizes.

*Tubing:* Steel and Tubes, Inc. (Unit of Republic Steel Corporation), Cleveland, Ohio. Sixty-eight page handbook of electric weld tubing, a comprehensive treatise carefully indexed and illustrated. Manufacture is briefly described, and information on weld characteristics, selection of materials, physical properties, trade terms and customs, surface finish, uses, cutting, bending, dimensions and many other topics is given.

*Unit Pulverizers:* The Strong-Scott Mfg. Co., Minneapolis, Minn. Three bulletins, showing applications of unit pulverizing equipment to small H.R.T. boilers, to Scotch marine boilers and to boilers in office and institutional buildings.

*Valves:* Gorton Heating Corporation, Cranford, N. J. Four-page pamphlet on equalizing steam- and vapor-heating systems and describing equalizing valves and air eliminators. The valves are designed especially to make all radiators heat evenly and quickly, and all rooms to be heated when the thermostat controlling an oil burner, stoker, or gas-fired boiler shuts off the fire.

*Welded Piping:* Air Reduction Sales Co., 60 E. 42nd St., New York City. The facts about welded piping for buildings, a 12-page booklet, summarizing the features of welded piping for small and medium-sized buildings, as well as for large commercial, institutional and public edifices.

*Welding Stainless Alloys:* Republic Steel Corporation (Central Alloy Division), Massillon, Ohio. Eighteen-page booklet containing information on various welding methods as applied to different types of stainless Enduro alloys, including electric arc welding, gas welding, spot and projection welding, seam welding and flash welding. The data and recommended methods are the result of research in the laboratory and in commercial welding shops.


# CLASSIFIED ADVERTISING

**8 cents for each word including heading and address. Count nine words for keyed address. Minimum $2.00 for each insertion. One inch $4.00. Cash must accompany order. Copy must be in our hands by the twenty-fifth of the month previous to issue.**

## SITUATIONS OPEN

SALESMEN WANTED—LEADING manufacturer of boilers, furnaces, air conditioners and water heaters has a few excellent territories open. Real business producers assured good income. Our present representatives know this ad is appearing. Address Key 210-A, "Heating, Piping and Air Conditioning," 1900 Prairie Avenue, Chicago.

## REPRESENTATIVES WANTED

RADIATOR SALES OPPORTUNITY—strong established manufacturer. Outstanding new advanced type heating radiator. High grade experienced sales representatives who can operate upon straight commission basis should write for complete particulars. State qualifications fully. Address Post Office Box 1222, Pittsburgh, Pennsylvania.

**Use This Page To Get What You Want**

**If you are looking for competent employes; or if you contemplate a change in position; have a patent for sale; second-hand machinery or tools; form a co-partnership, etc., your advertisement on this page will put you in touch with the people you desire to reach.**

**The cost of insertion is only eight cents a word and may mean many dollars to you.**

## SITUATIONS WANTED

SITUATION WANTED—MECHANical engineer, experienced in air conditioning and refrigeration, sales, design and erection. Member A. S. H. & V. E. Address Key 209-A, "Heating, Piping and Air Conditioning," 1900 Prairie Avenue, Chicago.

## FOR SALE

**HOME AIR CONDITIONING PATENT-PENDING SYSTEMS**

**Rights for sale. Covers every phase. Revolutionary. Address Key 211-A, "Heating, Piping and Air Conditioning," 1900 Prairie Avenue, Chicago.**

## LINES WANTED

**WELL ESTABLISHED COMPANY**

**desires agency in Pittsburgh for Boilers, Stokers and Specialties. Well acquainted with Architects, Engineers, Power and Heating Trades. Address Key 207-A, "Heating, Piping and Air Conditioning," 1900 Prairie Avenue, Chicago.**

# Index *to* Advertisers


Aerofin Corp. ..... 72
Allis-Chalmers Mfg. Co..... 6
American Air Filter Co..... 11
American Steam Pump Co..... 71
Armstrong Machine Works..... 78

Baker Ice Machine Co., Inc..... 72
Boylston Steam Specialty Co..... 76
Buffalo Forge Co..... 73
Byers Co., A. M..... 3

Commodore Heaters Corp..... 76
Coppus Engineering Corp..... 75
Crane Co..... 82

Dart Mfg. Co., E. M..... 74
Detroit Lubricator Co..... 70
Detroit Stoker Co..... 7

Emerson Electric Mfg. Co., The.... 69

Frick Company ..... 68

General Electric Co.....4 and 65

Harrisburg Pipe & Pipe Bending Co. 71
Hoffman Specialty Co., Inc..... 75

Jenkins Bros..... 77

Knowles Mushroom Ventilator Co... 78

Lincoln Electric Co., The.....
.....Inside Front Cover
Linde Air Products Co., The..... 10

Minneapolis-Honeywell Regulator Co. 12

Nash Engineering Co..... 16

Owens-Illinois Glass Co.....
.....Back Cover

Pittsburgh Steel Co..... 8

Ric-Wil Co., The ..... 76

Sarco Co., Inc..... 76
6th Midwest Engineering & Power Exposition ..... 77
Strong, Carlisle & Hammond Co..... 78
Sturtevant Co., B. F..... 66

Torrington Mfg. Co., The..... 9
Tube-Turns, Incorporated ..... 14

Vilter Mfg. Co., The..... 74

Wagner Electric Corp..... 67
Westinghouse Electric & Mfg. Co...
.....Inside Back Cover

Youngstown Sheet & Tube Co., The. 5